REPORT

OF THE

FIFTY-FIRST MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

YORK IN AUGUST AND SEPTEMBER 1881.

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1882.

Office of the Association: 22 ALBEMARLE STREET, LONDON, W.

CONTENTS.

Page

OBJECTS and Rules of the Association xxv

Places and Times of Meeting and Officers from commencement................ xxxii

Presidents and Secretaries of the Sections of the Association from commencement.. xxxix

Evening Lectures lii

Lectures to the Operative Classes.. liv

Officers of Sectional Committees present at the York Meeting lv

Treasurer's Account.. lvii

Table showing the Attendance and Receipts at Annual Meetings............ lviii

Officers and Council, 1881–82.. lx

Report of the Council to the General Committee.. lxi

Recommendations of the General Committee for Additional Reports and Researches in Science.. lxiii

Synopsis of Money Grants.. lxx

Places of Meeting in 1882 and 1883.. lxxi

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

Arrangement of the General Meetings.. lxxxii

Address by the President, Sir JOHN LUBBOCK, Bart., M.P., F.R.S., D.C.L., LL.D., Pres. L.S. 1

REPORTS ON THE STATE OF SCIENCE.

Report of the Committee, consisting of Professor SYLVESTER, Professor CAYLEY, and Professor SALMON, for the calculation of Tables of the Fundamental Invariants of Algebraic Forms 55

Report on Recent Progress in Hydrodynamics.—Part I. By W. M. HICKS, M.A.. 57

Report of the Committee, consisting of Sir WILLIAM THOMSON, Professor ROSCOE, Dr. J. H. GLADSTONE, and Dr. SCHUSTER (Secretary), appointed for the purpose of collecting information with regard to Meteoric Dust, and to consider the question of undertaking regular observations in various localities 88

Page

Second Report of the Committee, consisting of the Rev. Samuel Haughton, M.D., F.R.S., and Benjamin Williamson, F.R.S., appointed for the Calculation of Sun-heat Coefficients. Drawn up by Dr. Haughton 89

Fourteenth Report of the Committee, consisting of Professor Everett, Professor Sir William Thomson, Mr. G. J. Symons, Professor Ramsay, Professor Geikie, Mr. J. Glaisher, Mr. Pengelly, Professor Edward Hull, Dr. Clement Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, and Mr. A. Strahan, appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water. Drawn up by Professor Everett (Secretary) 90

Report of the Committee, consisting of Mr. G. H. Darwin, Professor Sir William Thomson, Professor Tait, Professor Grant, Dr. Siemens, Professor Purser, Professor G. Forbes, and Mr. Horace Darwin, appointed for the Measurement of the Lunar Disturbance of Gravity 93

Second Report of the Committee, consisting of Captain Abney, Professor W. G. Adams, and Professor G. Carey Foster, appointed to carry out an Investigation for the purpose of fixing a Standard of White Light............ 126

Final Report of a Committee, consisting of Professor A. S. Herschel, Professor W. E. Ayrton, Professor P. M. Duncan, Professor G. A. Lebour, Mr. J. T. Dunn, and Professor J. Perry, on Experiments to determine the Thermal Conductivities of certain Rocks, showing especially the Geological Aspects of the Investigation.. 126

Report of the Committee, consisting of Mr. James Heywood, F.R.S., Mr. William Shaen, Mr. Stephen Bourne, Mr. Robert Wilkinson, the Rev. W. Delany, Professor N. Story Maskelyne, M.P., F.R.S., Dr. Silvanus P. Thompson, Miss Lydia E. Becker, Sir John Lubbock, Bart., M.P., F.R.S., Professor A. W. Williamson, F.R.S., Mrs. Augusta Webster, and Dr. J. H. Gladstone, F.R.S. (Secretary), on the manner in which Rudimentary Science should be taught, and how examinations should be held therein, in Elementary Schools 148

Third Report of the Committee, consisting of Professor W. C. Williamson and Mr. W. H. Baily, appointed for the purpose of investigating the Tertiary Flora of the North of Ireland. Drawn up by William Hellier Baily, F.L.S., F.G.S., M.R.I.A. (Secretary) 152

Report of the Committee, consisting of Dr. J. H. Gladstone, Dr. W. R. E. Hodgkinson, Mr. W. Carleton Williams, and Dr. P. P. Bedson (Secretary), appointed for the purpose of investigating the Method of Determining the Specific Refraction of Solids from their Solutions 155

Fourth Report of the Committee, consisting of Professor Sir William Thomson, Dr. J. Merrifield, Professor Osborne Reynolds, Captain Douglas Galton, Mr. J. N. Shoolbred (Secretary), Mr. J. F. Deacon, and Mr. Rogers Field, appointed for the purpose of obtaining information respecting the Phenomena of the Stationary Tides in the English Channel and in the North Sea; and of representing to the Government of Portugal and the Governor of Madeira that, in the opinion of the British Association, Tidal Observations at Madeira or other islands in the North Atlantic Ocean would be very valuable, with a view to the advancement of our knowledge of the Tides in the Atlantic Ocean.. 160

Second Report of the Committee, consisting of Professor P. M. Duncan, F.R.S., and Mr. G. R. Vine, appointed for the purpose of reporting on Fossil Polyzoa. Drawn up by Mr. Vine (Secretary) 161

Report of the Committee, consisting of Dr. M. Foster, the late Professor Rolleston, Mr. Pye-Smith, Professor Huxley, Dr. Carpenter, Dr. Gwyn

Page

Jeffreys, Mr. F. M. Balfour, Sir C. Wyville Thomson, Professor Ray Lankester, Professor Allman, and Mr. Percy Sladen (Secretary), appointed for the purpose of aiding in the maintenance of the Scottish Zoological Station ... 177

Report of the Committee, consisting of Dr. M. Foster, Professor Rolleston, Mr. Dew-Smith, Professor Huxley, Dr. Carpenter, Dr. Gwyn Jeffreys, Mr. Sclater, Mr. F. M. Balfour, Sir C. Wyville Thomson, Professor Ray Lankester, Professor Allman, and Mr. Percy Sladen (Secretary), appointed for the purpose of arranging for the occupation of a Table at the Zoological Station at Naples ... 178

Report of the Committee, consisting of Mr. J. A. Harvie Brown, Mr. John Cordeaux, and Professor Newton, appointed at Swansea for the purpose of obtaining (with the consent of the Master and Brethren of the Trinity House, and of the Commissioners of Northern Lights) observations on the Migration of Birds at Lighthouses and Lightships, and of reporting on the same, at York, in 1881 ... 189

Report of the Committee, consisting of Lieut.-Colonel Godwin-Austen, Dr. G. Hartlaub, Sir J. Hooker, Dr. Günther, Mr. Seebohm, and Mr. Sclater, appointed to take steps for investigating the Natural History of Socotra ... 194

Report of the Committee, consisting of Mr. Sclater, Mr. Howard Saunders, and Mr. Thiselton Dyer, appointed for the purpose of investigating the Natural History of Timor-laut ... 197

Report on the Marine Fauna of the Southern Coast of Devon and Cornwall. By Spence Bate, F.R.S., and J. Brooking Rowe, F.L.S. ... 198

Report of the Committee, consisting of Professor A. C. Ramsay and Professor John Milne (Secretary), appointed for the purpose of investigating the Earthquake Phenomena of Japan ... 200

Ninth Report of the Committee, consisting of Professor Prestwich, Professor T. McK. Hughes, Professor W. Boyd Dawkins, Professor T. G. Bonney, the Rev. H. W. Crosskey, Dr. Deane, and Messrs. C. E. De Rance, D. Mackintosh, R. H. Tiddeman, J. E. Lee, J. Plant, W. Pengelly, W. Molyneux, H. G. Fordham, and W. Terrill, appointed for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation. Drawn up by the Rev. H. W. Crosskey, Secretary 204

Second Report of the Committee, consisting of Professor A. Leith Adams, the Rev. Professor Haughton, Professor Boyd Dawkins, and Dr. John Evans, appointed for the purpose of exploring the Caves of the South of Ireland ... 218

Report of the Committee, consisting of Sir F. J. Bramwell, Dr. A. W. Williamson, Professor Sir William Thomson, Mr. St. John Vincent Day, Dr. C. W. Siemens, Mr. C. W. Merrifield, Dr. Neilson Hancock, Mr. Abel, Captain Douglas Galton, Mr. E. H. Carbutt, Mr. Macrory, Mr. H. Trueman Wood, Mr. W. H. Barlow, and Mr. A. T. Atchison, appointed for the purpose of watching and reporting to the Council on Patent Legislation ... 222

Report of the Anthropometric Committee, consisting of Mr. F. Galton, Dr. Beddoe, Mr. Brabrook (Secretary and Reporter), Sir G. Campbell, Dr. Farr, Mr. F. P. Fellows, Major-General Pitt-Rivers, Mr. J. Park Harrison, Mr. James Heywood, Mr. P. Hallett, Professor Leone Levi, Dr. F. A. Mahomed, Dr. Muirhead, Sir Rawson Rawson, Mr. Charles Roberts, and the late Professor Rolleston ... 225

Report of the Committee, consisting of Professor Leone Levi, Mr. Stephen

Page

Bourne, Mr. Brittain, Dr. Hancock, Professor Jevons, and Mr. F. P. Fellows, appointed for the purpose of inquiring into and reporting on the present Appropriation of Wages, and other sources of income, and considering how far it is consonant with the economic progress of the people of the United Kingdom. Drawn up by Professor Leone Levi 272

Report of a Committee, consisting of James Glaisher, F.R.S., F.R.A.S., E. J. Lowe, F.R.S., Professor R. S. Ball, F.R.S., Dr. Walter Flight, F.G.S., and Professor A. S. Herschel, M.A., F.R.A.S., on Observations of Luminous Meteors during the year 1880–81 290

Report of the Committee, consisting of Professor Cayley, F.R.S., Professor G. G. Stokes, F.R.S., Professor H. J. S. Smith, F.R.S., Professor Sir William Thomson, F.R.S., Mr. James Glaisher, F.R.S., and Mr. J. W. L. Glaisher, F.R.S. (Secretary), on Mathematical Tables 303

Seventh Report of the Committee, consisting of Professor E. Hull, the Rev. H. W. Crosskey, Captain Douglas Galton, Mr. James Glaisher, Professor G. A. Lebour, Mr. W. Molyneux, Mr. G. H. Morton, Mr. W. Pengelly, Professor J. Prestwich, Mr. J. Plant, Mr. James Parker, Mr. I. Roberts, Mr. S. Stooke, Mr. G. J. Symons, Mr. W. Whitaker, and Mr. C. E. De Rance (Reporter), appointed for the purpose of investigating the Circulation of the Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations of England, and the Quality and Quantity of the Water supplied to towns and districts from these formations 309

Report of the Committee, consisting of Professor Dewar, Dr. Williamson, Dr. Marshall Watts, Captain Abney, Mr. Stoney, Professor W. N. Hartley, Professor McLeod, Professor Carey Foster, Professor A. K. Huntington, Professor Emerson Reynolds, Professor Reinold, Professor Liveing, Lord Rayleigh, Dr. Arthur Schuster, and Mr. W. Chandler Roberts (Secretary), appointed for the purpose of reporting upon the present state of our Knowledge of Spectrum Analysis 317

Interim Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements, the Committee consisting of Professor G. Carey Foster, Mr. C. Hockin, Professor Sir William Thomson, Professor Ayrton, Mr. J. Perry, Professor W. G. Adams, Lord Rayleigh, Professor F. Jenkin, Dr. O. J. Lodge, Dr. John Hopkinson, Dr. Muirhead, Mr. W. H. Preece, and Mr. Herbert Taylor 423

On some New Theorems on Curves of double Curvature. By Professor Sturm 440

Observations of Atmospheric Electricity at the Kew Observatory during 1880. By G. M. Whipple, B.Sc., F.R.A.S., F.M.S., Superintendent 443

On the Arrestation of Infusorial Life by Solar Light. By Professor John Tyndall, F.R.S 450

On the Effects of Oceanic Currents upon Climates. By the Rev. Samuel Haughton, M.D., F.R.S. 451

On Magnetic Disturbances and Earth-currents. By Professor William Grylls Adams, F.R.S. 463

On some applications of Electric Energy to Horticultural and Agricultural purposes. By C. Wm. Siemens, D.C.L., LL.D., F.R.S., Mem. Inst. C.E. 474

On the Pressure of Wind upon a Fixed Plane Surface. By Thomas Hawksley, C.E., F.R.S. 480

On the Island of Socotra. By Bayley Balfour, Sc.D., M.B., Regius Professor of Botany, University of Glasgow 482

On some of the Developments of Mechanical Engineering during the last half-century. By Sir Frederick Bramwell, V.P. Inst. C.E., F.R.S. 494

TRANSACTIONS OF THE SECTIONS.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

THURSDAY, SEPTEMBER 1.

Page

Address by Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S.L. and E., President of the Section 513

1. On the Possibility of the Existence of Intra-Mercurial Planets. By Balfour Stewart, LL.D., F.R.S. 518
2. On the Photographic Spectrum of Comet 'b' 1881. By William Huggins, D.C.L., LL.D., F.R.S. 520
3. On a Prismatic Optometer. By Tempest Anderson, M.D., B.Sc. 521
4. On the Effects of the Lunar and Solar Tide in increasing the Length of the Sidereal Day. By the Rev. Samuel Haughton, M.D., F.R.S. 523
5. On the Effects of Oceanic Currents upon Climates. By the Rev. Samuel Haughton, M.D., F.R.S. 523
6. On some applications of Electric Energy to Horticultural and Agricultural purposes. By Dr. C. Wm. Siemens, F.R.S. 524
7. On Hydrocarbons in the Solar Atmosphere. By Captain Abney, R.E., F.R.S. 524

FRIDAY, SEPTEMBER 2

Physical Department.

1. On Surface-tension and Capillary Action. By Professor Osborne Reynolds, F.R.S. 524
2. On some Colour Experiments. By Lord Rayleigh, F.R.S. 526
3. On a Question in the Theory of Lighting. By Lord Rayleigh, F.R.S. 526
4. On some uses of Faure's Accumulator in connection with Lighting by Electricity. By Professor Sir William Thomson, M.A., F.R.S. 526
5. On the Economy of Metal in Conductors of Electricity. By Professor Sir William Thomson, M.A., F.R.S. 526
6. On the proper Proportions of Resistance in the Working Coils, the Electro-Magnets, and the External Circuits of Dynamos. By Professor Sir William Thomson, M.A., F.R.S. 528
7. On the Application of Electricity to the Localisation of a Bullet in a Wound. By W. H. Preece, F.R.S. 531
8. On some of Bell and Tainter's recent Researches and their Consequences. By W. Lant Carpenter, B.A., F.C.S. 531

Page

9. On the Electric Conductivity and Dichroic Absorption of Tourmaline. By Professor SILVANUS P. THOMPSON, B.A., D.Sc. 531
10. On the arrangement of Cometic Perihelia with reference to the Sun's march in space. By HENRY MUIRHEAD, M.D. 532

MATHEMATICAL DEPARTMENT.

1. Second Report of the Committee appointed for the calculation of Tables of the Fundamental Invariants of Algebraic Forms 532
2. Report of the Committee on Mathematical Tables 532
3. Report on Recent Progress in Hydrodynamics.—Part I. By W. M. HICKS, M.A. 532
4. Sur un critérium de Steiner relatif à la théorie des sections coniques. Par M. HALPHEN 532
5. Some new Theorems on Curves of double Curvature. By Professor STURM 534
6. On Congruencies of the Second Order and Second Class. By Dr. T. ARCHER HIRST, F.R.S. 534
7. Sur les faisceaux de forme biquadratique binaire ayant une même Jacobienne. Par CYPARISSOS STEPHANOS 534
8. On a Diagram connected with the Transformation of Elliptic Functions. By Professor CAYLEY, F.R.S. 534
9. A partial Differential Equation connected with the simplest case of Abel's Theorem. By Professor CAYLEY, F.R.S. 534
10. On the Differential Equations satisfied by the Modular Equations. By Professor H. J. S. SMITH, M.A., F.R.S. 535
11. On the q-Series in Elliptic Functions. By J. W. L. GLAISHER, M.A., F.R.S. 535
12. On the Elucidation of a Question in Kinematics by the aid of Non-Euclidian Space. By ROBERT S. BALL, LL.D., F.R.S. 535
13. On a Theorem relating to the Description of Areas. By WILLIAM WOOLSEY JOHNSON, Professor of Mathematics in the Naval Academy, Annapolis, U.S. 536
14. On the Equation of the Multiplier in the Theory of Elliptic Transformation. By Professor H. J. S. SMITH, M.A., F.R.S. 538
15. On a Linear relation between two Quadratic Surds. By Professor H. J. S. SMITH, M.A., F.R.S. 538
16. On a Class of Binodal Quartics. By Professor R. W. GENESE, M.A. 538

SATURDAY, SEPTEMBER 3.

1. On a Class of Differential Equations. By Professor HALPHEN 538
2. On the Aspects of Points in a Plane. By Professor HALPHEN 538
3. On a Connection between Homographies in a Straight Line and Points in a Space. By CYPARISSOS STEPHANOS 538
4. On Involutional (1 1) Correspondence. By Professor GENESE, M.A. 539
5. On the Velocity Function of a Liquid due to the Motion of Cylinders and Surfaces of Revolution. By A. G. GREENHILL 540

MONDAY, SEPTEMBER 5.

PHYSICAL DEPARTMENT.

Page
1. Report of the Committee on Meteoric Dust 540
2. Report of the Committee on Tidal Observations in the English Channel and the North Sea 540
3. Report of the Committee on Underground Temperature 540
4. Report of the Committee on the Calculation of Sun-heat Coefficients 540
5. Observations of Atmospheric Electricity at the Kew Observatory during 1880. By G. M. WHIPPLE, B.Sc., F.R.A.S. 540
6. On a Universal Sunshine Recorder Stand. By G. M. WHIPPLE, B.Sc., F.R.A.S. 540
7. On the Calibration of Mercurial Thermometers by Bessel's Method. By Professors T. E. THORPE, Ph.D., F.R.S., and A. W. RÜCKER, M.A. 540
8. On the General Coincidence between Sun-spot Activity and Terrestrial Magnetic Disturbance. By the Rev. F. HOWLETT, F.R.A.S. 541
9. On Magnetic Disturbances and Earth-currents. By Professor W. GRYLLS ADAMS, F.R.S. 542
10. On the Arrestation of Infusorial Life by Solar Light. By Professor JOHN TYNDALL, F.R.S. 543
11. On a new Integrating Anemometer. By the Rev. J. M. WILSON, M.A., and H. S. HELE SHAW 543
12. On the Isothermals of the British Isles. By ALEX. BUCHAN, M.A., F.R.S.E. 544
13. On the Diurnal Period of Hailstorms. By ALEX. BUCHAN, M.A., F.R.S.E. 544
14. On the Sunspot Period, and Planetary Tides in the Solar Atmosphere. By F. B. EDMONDS 544
15. Some Laws which regulate the Succession of Mean Temperature and Rainfall in the Climate of London. By H. COURTENAY FOX, M.R.C.S. 544
16. On the Blowing Wells near Northallerton. By THOMAS FAIRLEY, F.R.S.E. 544
17. Some Remarks on Artificial Flight. By FRED. W. BREAREY, Hon. Secretary of the Aeronautical Society 545
18. On the desirability of observing Occultations of Stars, of the first and other bright magnitudes, from places where they are to be seen near the horizon. By H. S. WILLIAMS, M.A., F.R.A.S. 547

MATHEMATICAL DEPARTMENT.

1. Sur la représentation des rotations autour d'un point par des points de l'espace. By CYPARISSOS STEPHANOS 547
2. On the Polar Planes of a point with respect to four Quadric Surfaces. By W. SPOTTISWOODE, M.A., Pres. R.S. 547
3. On the Extension of the Theory of Screws to the Dynamics of any material system. By ROBERT S. BALL, LL.D., F.R.S., Royal Astronomer of Ireland 547
4. On a Property of a small Geodesic Triangle on any surface. By Professor H. J. S. SMITH, M.A., F.R.S. 548

Page

5. On the General Analogy between the formulæ of singly and doubly Periodic Functions. By J. W. L. GLAISHER, M.A., F.R.S. 548
6. Sur les Séries Hypergéométriques. By Professor HALPHEN.................. 551

TUESDAY, SEPTEMBER 6.

1. Report of the Committee on Electrical Standards 551
2. Report of the Committee for the Measurement of the Lunar Disturbance of Gravity 551
3. On the Rainfall Observations made upon York Minster by Professor John Phillips, F.R.S. By G. J. SYMONS, F.R.S. 551
4. On Volta-Electric Inversion. By Professor SILVANUS P. THOMPSON, B.A., D.Sc.. 552
5. On the Rotational Coefficient in various Metals. By E. H. HALL......... 552
6. On a Dynamometer Coupling. By Professors W. E. AYRTON, F.R.S., and JOHN PERRY, B.E. 553
7. On an Early Attempt at a Secondary Battery. By Dr. C. W. SIEMENS, F.R.S. 554
8. On an Electro-Ergometer. By Professor Sir WILLIAM THOMSON, M.A., F.R.S. 554
9. On a Problem in Stream Lines. By Professor A. W. RÜCKER, M.A....... 554
10. On Potential due to Contact. By S. LAVINGTON HART, B.A., D.Sc., Scholar of St. John's College, Cambridge 555
11. On the Electric Discharge through Colza Oil. By A. MACFARLANE, M.A., D.Sc., F.R.S.E. 556
12. Représentation graphique de la Formule des Piles. Discussion. Par le Professeur C. M. GARIEL, Agrégé de Physique à la Faculté de Médecine de Paris, Ingénieur des Ponts et Chaussées.. 556
13. On an Easy Method of making Carbon Cells for Galvanic Batteries. By W. SYMONS, F.C.S. 557
14. On an Antimonized Cellular Carbon Galvanic Battery. By W. SYMONS, F.C.S. 557
15. On the Absolute Sine Electrometer. By Professor G. M. MINCHIN, M.A. 558

WEDNESDAY, SEPTEMBER 7.

1. Report of the Committee on a Standard of White Light 559
2. Report of the Committee on Luminous Meteors.................................. 559
3. Report of the Committee on the Thermal Conductivity of Rocks............ 559
4. A Contribution to the History of the Algebra of Logic. By the Rev. R. HARLEY, F.R.S. 559
5. On the Illuminating Powers of Incandescent Vacuum Lamps with measured Potentials and measured Currents. By Professor Sir WILLIAM THOMSON, M.A., F.R.S., and JAMES T. BOTTOMLEY, M.A. 559
6. On Photometry, with Experiments. By Professor Sir WILLIAM THOMSON, M.A., F.R.S. 561
7. On the Dynamical Theory of Radiation. By Professor ARTHUR SCHUSTER, Ph.D., F.R.S. 561
8. On a New Electrometer and some preliminary Experiments on Voltaic Action. By J. BROWN 562

Page

9. On a Wave Apparatus for Lecture purposes, to illustrate Fresnel's conception of Polarised Light. By C. J. WOODWARD, B.Sc. 563
10. On a Microscope with arrangements for illuminating the sub-stage. By EDWARD CROSSLEY, F.R.A.S. 563
11. On a New Polarising Prism. By Professor SILVANUS P. THOMPSON, B.A., D.Sc. 563
12. On an Overlapping Spectroscope. By JAMES LOVE, F.R.A.S., F.G.S. ... 564
13. On Change of Density at the Melting Point. By JAMES LOVE, F.R.A.S., F.G.S. 564
14. On Drops and Capillarity. By Dr. T. WOODS 565
15. On Binaural Audition.—Part III. By Professor SILVANUS P. THOMPSON, B.A., D.Sc. 565
16. On Differential Resolvents. By the Rev. ROBERT HARLEY, F.R.S.......... 565
17. An Analysis of Relationships. By A. MACFARLANE, M.A., D.Sc., F.R.S.E. 566

SECTION B.—CHEMICAL SCIENCE.

THURSDAY, SEPTEMBER 1.

1. Report of the Committee on the Method of Determining the Specific Refraction of Solids from their Solutions.......... 567
2. On a Process for Utilising Waste-products and Economising Fuel in the Extraction of Copper. By J. DIXON 567
3. On Metallic Compounds containing Bivalent Hydrocarbon Radicals. Part II. By J. SAKURAI 567
Address by Professor A. W. WILLIAMSON, Ph.D., LL.D., F.R.S., V.P.C.S., President of the Section 568
4. On the Chemical Action between Solids. By Professor T. E. THORPE, Ph.D., F.R.S. 580
5. On the First Two Lines of Mendelejeff's Table of Atomic Weights. By W. WELDON, F.R.S.E. 580
6. On the Occlusion of Gaseous Matter by Fused Silicates at High Temperatures, and its possible connection with Volcanic Agencies. By I. LOWTHIAN BELL, F.R.S. 580
7. On the Siliceous and other Hot Springs in the Volcanic District of the North Island of New Zealand. By WM. LANT CARPENTER, B.A., B.Sc., F.C.S. 580

FRIDAY, SEPTEMBER 2.

1. Second Report of the Committee upon the present state of our Knowledge of Spectrum Analysis 582
2. On the Fluid Density of certain Metals. By Professor W. CHANDLER ROBERTS, F.R.S., and T. WRIGHTSON 582
3. On the Oxides of Manganese. By V. H. VELEY, B.A. 582
4. On the Inferences deducible from high Molecular Weights, as exhibited by the Oxides of Manganese. By Professor W. ODLING, F.R.S. 582
5. On Manganese Nodules, and their Occurrence on the Sea-bottom. By J. Y. BUCHANAN 583
6. On Brewing in Japan. By Professor R. W. ATKINSON, B.Sc. (Lond.) ... 585

Page

7. On Peppermint-camphor (Menthol) and some of its Derivatives. By Professor R. W. Atkinson, B.Sc. (Lond.), and H. Yoshida 585

8. On the Sodium-alum of Japan. By Professor Edward Divers, M.D. ... 586

9. On the Occurrence of Selenium and Tellurium in Japan. By Professor Edward Divers, M.D. 586

10. On the Chrome Iron Ore of Japan. By Professor Edward Divers, M.D. 587

MONDAY, SEPTEMBER 5.

1. On certain Points in Modern Progress in Chemical Knowledge. By Professor H. E. Armstrong, Ph.D., F.R.S. 589

2. On the alleged Decomposition of the Elements. By Professor Dewar, M.A., F.R.S. 589

3. On the Production of Crystals by the Action of Metals in Carbon Disulphide in Sealed Tubes. By Philip Braham, F.C.S. 589

4. On the Separation of Hydrocarbon Oils from Fat Oils. By Alfred H. Allen, F.C.S. 589

5. On some Phenomena which appear to be of the Nature of Chemico-Magnetic Action. By William Thomson, F.R.S.E. 590

6. On the Specific Refraction and Dispersion of Light by Liquids. By J. H. Gladstone, Ph.D., F.R.S. 591

7. On Molecular Attraction. By F. D. Brown, B.Sc. 592

8. Note on a new Method of Measuring certain Chemical Affinities 592

TUESDAY, SEPTEMBER 6.

1. On the present state of Chemical Nomenclature. By Professor A. W. Williamson, Ph.D., F.R.S. 593

2. On Alterations in the Properties of the Nitric Ferment by Cultivation. By R. Warington, F.C.S. 593

3. On the Effect of the Spectrum of Silver Chloride. By Captain Abney, R.E., F.R.S. 594

4. Some Remarks on Crystallogeny. By Professor J. P. Cooke 595

5. On the Action of Zinc and Magnesium on Acidified Solutions of Ferric Sulphate. By Professor T. E. Thorpe, Ph.D., F.R.S. 595

6. On the Reducing Action of Zinc and Magnesium on Vanadium Solutions. By Professor H. E. Roscoe, LL.D., F.R.S. 596

7. On the Determination of the Relative Atomic Weights of Manganese, Oxygen, and Silver. By Professor Dewar, M.A., F.R.S., and A. Scott, B.A., B.Sc. 596

WEDNESDAY, SEPTEMBER 7.

1. On Some Vapour Density Determinations. By Professor Dewar, M.A., F.R.S., and A. Scott, B.A., B.Sc. 597

2. On Vapour Density Determinations. By Professor Thorpe, Ph.D., F.R.S. 597

3. Note on the Phosphates of Lime and Ammonia. By J. Alfred Wanklyn 597

4. On a New System of Blowpipe Analysis. By Lieut.-Colonel Ross......... 598

5. On Colliery Explosions. By William Galloway.................................. 598

6. On the Double Iodide of Mercury and Copper. By Professor Silvanus P. Thompson, B.A., D.Sc. 600

Page

7. Analyses of the Water and Gas from Blowing Wells near Northallerton. By T. FAIRLEY, F.R.S.E. 601
8. On Experiments with Manures on the Barley Crop of 1881. By W. IVISON MACADAM 602
9. On the Hydration of Salts and Oxides. By C. F. CROSS, B.Sc. 602
10. On Cellulose and Coal. By C. F. CROSS, B.Sc., and E. J. BEVAN 603
11. On the New Element, Actinium. By Dr. T. L. PHIPSON, F.C.S. 603
12. On Bowkett's Thermograph. By WM. LANT CARPENTER, B.A., B.Sc., F.C.S. 604

SECTION C.—GEOLOGY.

THURSDAY, SEPTEMBER 1.

Address by ANDREW CROMBIE RAMSAY, LL.D., F.R.S., F.G.S., President of the Section 605
1. On the Laurentian Beds of Donegal and of other parts of Ireland. By Professor EDWARD HULL, LL.D., F.R.S., Director of the Geological Survey of Ireland 609
2. On the Laurentian Rocks in Ireland. By G. H. KINAHAN, M.R.I.A., &c. 609
3. Life in Irish and other Laurentian Rocks. By C. MOORE, F.G.S. 610
4. On the occurrence of Granite *in sitû*, about 20 miles S.W. of the Eddystone. By A. R. HUNT, M.A., F.G.S 610
5. Some Observations on the Causes of Volcanic Action. By Professor J. PRESTWICH, M.A., F.R.S. 610
6. The Connection between the Intrusion of Volcanic Rock and Volcanic Eruptions. By Professor SOLLAS, M.A., F.R.S.E 613

FRIDAY, SEPTEMBER 2.

1. On the Influence of Barometric Pressure on the Discharge of Water from Springs. By BALDWIN LATHAM, M. Inst. C.E., F.G.S., F.M.S. 614
2. Glacial Sections at York, and their relation to the later deposits. By J. EDMUND CLARK, B.A., B.Sc., F.G.S. 614
3. On the Bridlington and Dimlington Glacial Shell-beds. By G. W. LAMPLUGH 616
4. On Sections of the Drift obtained from the new Drainage Works of Driffield. By J. R. MORTIMER 617
5. On the Subsidences above the Permian Limestone between Hartlepool and Ripon. By A. G. CAMERON, Geological Survey of England and Wales 617
6. The Glacial Deposits of West Cumberland. By J. D. KENDALL, C.E., F.G.S. 617
7. On Simosaurus pusillus (Fraas), a step in the Evolution of the Plesiosauria. By Professor H. G. Seeley, F.R.S., F.L.S. 618
8. On a Restoration of the Skeleton of Archæopteryx, with some remarks on the differences between the Berlin and London specimens. By Professor H. G. SEELEY, F.R.S., F.L.S. 618

SATURDAY, SEPTEMBER 3.

Page

1. On Asterosmilia Reedi, a new species of coral from the Oligocene of Brockenhurst, Hants. By Professor P. MARTIN DUNCAN, F.R.S. 618
2. On the Strata between the Chillesford Beds and the Lower Boulder Clay, 'The Mundesley and Westleton Beds.' By Professor J. PRESTWICH, M.A., F.R.S. 620
3. On the Extension into Essex, Middlesex, and other Inland Counties, of the Mundesley and Westleton Beds, in relation to the age of certain hill-gravels and of some of the valleys of the South of England. By Professor J. PRESTWICH, M.A., F.R.S. 620
4. A preliminary account of the working of Dowkerbottom Cave, in Craven, during August, 1881. By E. B. POULTON, M.A., F.G.S. 622

MONDAY, SEPTEMBER 5.

1. Seventh Report on the Circulation of the Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations of England, and the Quality and Quantity of the Water supplied to various towns and districts from these formations 623
2. Third Report on the Tertiary (Miocene) Flora of the Basalt of the North of Ireland........ 623
3. On the Formation of Coal. By EDWARD WETHERED, F.G.S., F.C.S....... 623
4. Preliminary Remarks on the Microscopic Structure of Coal. By Professor W. C. WILLIAMSON, F.R.S. 625
5. On the Halifax Hard Seam. By W. CASH, F.G.S. 626
6. Researches in Fossil Botany. By JAMES SPENCER 627
7. Notes on Astromyelon and its root. By JAMES SPENCER 628
8. On the Palæozoic Rocks of North Devon and West Somerset. By W. A. E. USSHER, F.G.S., Geological Survey of England and Wales........ 629
9. The Devono-Silurian Formation. By Professor E. HULL, LL.D., F.R.S. 631
10. On Evaporation and Eccentricity as Co-factors in Glacial Periods. By the Rev. E. HILL, M.A. 631
11. On the Discovery of Coal-Measures under New Red Sandstone, and on the so-called Permian Rocks of St. Helen's, Lancashire. By A. STRAHAN, M.A., F.G.S., Geological Survey of England and Wales 632
12. On the Upper Bagshot Sands of Hordwell Cliff, Hampshire. By E. B. TAWNEY, M.A., F.G.S. 633

TUESDAY, SEPTEMBER 6.

1. Ninth Report on the Erratic Blocks of England, Wales, and Ireland 633
2. Report on Fossil Polyzoa........ 633
3. On 'Flots.' By J. R. DAKYNS, M.A., Geological Survey of England and Wales 634
4. Remarks upon the Structure and Classification of the Blastoidea. By P. HERBERT CARPENTER, M.A. 634
5. On the Characters of the 'Lansdown Encrinite' (Millericrinus Prattii, *Gray, sp.*) By P. HERBERT CARPENTER, M.A. 635
6. On the Lower Keuper Sandstone of Cheshire. By A. STRAHAN, M.A., F.G.S., Geological Survey of England and Wales 635
7. On a Discovery of Fossil Fishes in the New Red Sandstone of Nottingham. By E. WILSON, F.G.S. 637

Page

8. On the Rhætics of Nottinghamshire. By E. Wilson, F.G.S. 637
9. The Great Plain of Northern India not an old Sea-basin. By W. T. Blanford, F.R.S., F.G.S., &c. 638
10. The Gold Fields, and the Quartz-outcrops of Southern India. By William King, Deputy Superintendent (for Madras), Geological Survey of India 639
11. On the Geology of the Island of Cyprus. By R. Russell, C.E. 640
12. Observations on the two types of Cambrian beds of the British Isles (the Caledonian and Hiberno-Cambrian), and the conditions under which they were respectively deposited. By Professor Edward Hull, LL.D., F.R.S. 642
13. On the Lower Cambrian of Anglesea. By Professor T. McK. Hughes, M.A., F.G.S. 643
14. On the Gnarled Series of Amlwch and Holyhead in Anglesea. By Professor T. McK. Hughes, M.A., F.G.S. 644
15. The Subject-matter of Geology, and its Classification. By Professor W. J. Sollas, M.A., F.G.S. 644
16. On the Exploration of a Fissure in the Mountain Limestone at Raygill. By James W. Davis, F.G.S., F.L.S. 645
17. On the Zoological position of the genus *Petalorhynchus*, Ag., a Fossil Fish from the Mountain Limestone. By James W. Davis, F.G.S., F.L.S. 646
18. On *Diodontopsodus*, Davis, a new genus of Fossil Fishes from the Mountain Limestone, at Richmond, in Yorkshire. By James W. Davis, F.G.S., F.L.S. 646

WEDNESDAY, SEPTEMBER 7.

1. Report on the Earthquake Phenomena of Japan 646
2. A Contribution to Seismology. By John Milne, F.G.S., and Thomas Gray, B.Sc., F.R.S.E. 646
3. Final Report on the Thermal Conductivities of certain Rocks, showing especially the Geological Aspects of the Investigation 647
4. On an International Scale of Colours for Geological Maps. By W. Topley, Geological Survey of England and Wales 647
5. On the Glacial Geology of Central Wales. By Walter Keeping, M.A., F.G.S., Keeper of the York Museum 648
6. On some points in the Morphology of the Rhabdophora. By John Hopkinson, F.L.S., F.G.S. 649
7. On some Ores and Minerals from Laurium, Greece. By H. Stopes, F.G.S. 650
8. Notes on the Cheshire Salt-field. By C. E. De Rance, F.G.S., Assoc. Inst. C.E. 650
9. On some sections in the Lower Palæozoic Rocks of the Craven District. By J. E. Marr, B.A., F.G.S. 650

Section D.—BIOLOGY.

Department of Zoölogy and Botany.

THURSDAY, SEPTEMBER 1.

Address by Richard Owen, C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.Z.S., President of the Section 651

Page

1. Report of the Committee for the Investigation of the Natural History of Socotra 661
2. Report of the Committee for the Investigation of the Natural History of Timor-laut 661
3. Report on the Record of Zoological Literature 661

FRIDAY, SEPTEMBER 2.

1. Jurassic Birds and their Allies. By Professor O. C. MARSH 661
2. On the use of the Chitinous Elements or Appendages of the Cheilostomatous Polyzoa in the Diagnosis of Species. By GEORGE BUSK, F.R.S. 662
3. On the Botany of Madagascar. By J. G. BAKER, F.R.S., F.L.S. 663
4. On the Colours of Spring Flowers. By ALFRED W. BENNETT, M.A., B.Sc., F.L.S. 666
5. On the Constancy of Insects in their Visits to Flowers. By ALFRED W. BENNETT, M.A., B.Sc., F.L.S. 667
6. On the Mode in which the Seed of *Stipa* buries itself in the ground. By Sir JOHN LUBBOCK, Bart., M.P., F.R.S. 668

SATURDAY, SEPTEMBER 3.

1. On the Insect House in the Gardens of the Zoological Society of London. By P. L. SCLATER, M.A., Ph.D., F.R.S., Secretary to the Zoological Society of London 668
2. On the Birds which have bred in the Barnsley and South Yorkshire District. By THOMAS LISTER 670
3. On the Foot of Birds, and on the Use of the Serrated Claw. By PHILIP M. C. KERMODE 670

MONDAY, SEPTEMBER 5.

1. On the Anatomy and Classification of the Petrels, based upon those collected by H.M.S. 'Challenger.' By W. A. FORBES, B.A., F.L.S., F.Z.S. 671
2. On some Permanent Larval Forms among the *Crinoidea*. By P. HERBERT CARPENTER, M.A. 671
3. Note on the British *Comatulæ*. By P. HERBERT CARPENTER, M.A. 672
4. On the Affinities of Proneomenia. By Dr. A. A. W. HUBRECHT 673
5. Report on the Migration of Birds 675
6. On some Points in the Development of *Osmunda regalis* (Linn.). By CHAS. P. HOBKIRK, F.L.S. 675

TUESDAY, SEPTEMBER 6.

1. On the Sense of Colour among some of the Lower Animals. By Sir JOHN LUBBOCK, Bart., M.P., F.R.S. 676
2. Report of the Committee on the Zoological Station at Naples 677
3. Report of the Committee on the Scottish Zoological Station 677
4. On our present Knowledge of the Fauna inhabiting British India and its Dependencies. By W. T. BLANFORD, F.R.S. 677
5. On a Fossil Stem from the Halifax Coal-measures. By THOMAS HICK, B.A., B.Sc., and WILLIAM CASH, F.G.S. 679

Page

6. Notes on Chlamydomyxa. By P. A. GEDDES 680
7. On a New Sub-Class of Infusorians. By P. A. GEDDES 680
8. On the Improvement of Freshwater Fisheries. By Lieut.-General Sir JAMES E. ALEXANDER, Knt., C.B., F.R.S.E. 680
9. On some Vestiges of the Ancient Forest of part of the Pennine Chain. By JOSEPH LUCAS 680
10. Report on the Marine Fauna of the Southern Coast of Devon and Cornwall 681

DEPARTMENT OF ANTHROPOLOGY.

THURSDAY, SEPTEMBER 1.

Address by Professor W. H. FLOWER, LL.D., F.R.S., F.R.C.S., F.L.S., F.G.S., Pres. Z.S., Chairman of the Department 682
1. Report on the Exploration of the Caves of the South of Ireland 689
2. On the Stature of the Inhabitants of Hungary. By Dr. BEDDOE, F.R.S. 689

FRIDAY, SEPTEMBER 2.

1. The Viking's Ship, discovered at Sandefjord in Norway, 1880. By J. HARRIS STONE, M.A., F.L.S., F.C.S. 689
2. On Excavations in the Earthwork called Danes' Dyke at Flamborough, and on the Earthworks of the Yorkshire Wolds. By Major-General PITT-RIVERS, F.R.S. (formerly Colonel Lane-Fox) 690
3. On the Application of Composite Portraiture to Anthropological purposes. By FRANCIS GALTON, F.R.S. 690
4. Account of the Discovery of Six Ancient Dwellings, found under and near to British Barrows on the Yorkshire Wolds. By J. R. MORTIMER 691
5. On the Origin and Use of Oval Tool-stones. By W. J. KNOWLES 692
6. On the Discovery of Flint Implements in stratified gravel in the Nile Valley, near Thebes. By Major-General PITT-RIVERS, F.R.S. (formerly Colonel Lane-Fox) 693

SATURDAY, SEPTEMBER 3.

1. Report of the Anthropometric Committee 693
2. On a Collection of Racial Photographs. By J. PARK HARRISON, M.A. 693
3. On Scandinavian and Pictish Customs on the Anglo-Scottish Border. By Dr. PHENÉ, F.S.A., F.R.G.S. 693
4. On some Objects recently exhumed in Britain, of apparently Phœnician origin. By Dr. PHENÉ, F.S.A., F.R.G.S. 695

MONDAY, SEPTEMBER 5.

1. Notes on the Geographical Distribution of Mankind. By Miss A. W. BUCKLAND 695
2. On the Papuans and the Polynesians. By C. STANILAND WAKE 696
3. On Excavations in a camp called Ambresbury Banks in Epping Forest. By Major-General PITT-RIVERS, F.R.S. (formerly Colonel Lane-Fox) 697
4. On the Relation of Stone Circles to Outlying Stones or Tumuli or Neighbouring Hills, with some inferences therefrom. By A. L. LEWIS 697

Page

5. Notes on some specimens of Saw-cuts and Drill-holes in hard Stones of Primeval Egyptian period. By W. FLINDERS PETRIE 697
6. On the Numeral and Philological relations of the Hebrew, Phœnician, or Canaanitic Alphabet and the Language of the Khita Inscriptions. By HYDE CLARKE 698
7. The Early Colonisation of Cyprus and Attica, and its relation to Babylonia. By HYDE CLARKE 698
8. On the Animism of the Indians of British Guiana. By EVERARD F. IM THURM 699
9. Origin and Primitive Home of the Semites. By G. BERTIN 699
10. On the Utilisation of the Memory. By GEORGE HARRIS, LL.D., F.S.A. 699
11. On the Cultivation of the Senses. By GEORGE HARRIS, LL.D., F.S.A... 699

TUESDAY, SEPTEMBER 6.

1. Traces of Man in the Crag. By H. STOPES, F.G.S. 700
2. The Results of recent further Excavations in the Caves of Cefn, near St. Asaph, North Wales. By Professor T. McK. HUGHES, M.A., and Mrs. WILLIAMS WYNN 700
3. Exhibition of a Roman Bronze galeated Bust. By Professor T. McK. HUGHES, M.A. 701
4. Exhibition of Four Bronze Socketed Spears, probably ancient, from China. By Professor T. McK. HUGHES, M.A. 701
5. On a supposed Inscribed Stone, near Llanerchymedd, in Anglesea. By Professor T. McK. HUGHES, M.A. 701
6. On some late Celtic Engravings on a Slate Tablet, found at Towyn. By J. PARK HARRISON, M.A. 701
7. On the Physical Characters and Proportions of the Zulus. By C. ROBERTS, F.R.C.S., and GEORGE W. BLOXAM, M.A., F.L.S., Assistant Secretary of the Anthropological Institute 702
8. Exhibition of Stone Implements from Asia Minor. By HYDE CLARKE ... 703
9. On certain Discoveries of Bronze Implements in and about Leeds. By JOHN HOLMES 703
10. On the Profile of the Danes and Germans. By J. PARK HARRISON, M.A. 703
11. On a remarkable Human Skull found near York. By EDWARD ALLEN, F.G.S. 704

DEPARTMENT OF ANATOMY AND PHYSIOLOGY.

FRIDAY, SEPTEMBER 2.

Address by Professor J. S. BURDON SANDERSON, M.D., LL.D., F.R.S., Chairman of the Department 705
1. On the Development of the Colour-sense. By Dr. MONTAGU LUBBOCK ... 715
2. On the Function of the Two Ears in the Perception of Space. By Professor SILVANUS P. THOMPSON, B.A., D.Sc. 716
3. A Contribution to the Question on the Influence of Bacilli in the Production of Disease. By Professor J. COSSAR EWART, M.D. 717
4. On a little-known Cranial Difference between the Catarrhine and Platyrrhine Monkeys. By W. A. FORBES, B.A. 718

MONDAY, SEPTEMBER 5.

Page

1. On the Homology of the Conario-hypophysial Tract, or of the so-called 'Pineal' and 'Pituitary Glands.' By Professor R. Owen, M.D., C.B., F.R.S. 719
2. On the Acetabulum of Animals in which the Ligamentum Teres is described as wanting. By Professor Struthers, M.D. 720
3. On the Correspondence between the Articulations of the Metacarpal and Metatarsal Bones in Man. By Professor Struthers, M.D. 721
4. On the Pronephros of Teleosteans and Ganoids. By F. M. Balfour, M.A., F.R.S. 721
5. On the Digastric Muscle, its Modifications and Functions. By G. E. Dobson 722
6. On the Causes and Results of assumed Cycloidal Rotation in Arterial Red Discs. By R. W. Woollcombe 722
7. Observations on the Incubation of the Indian Python (*Python molurus*). By W. A. Forbes, B.A. 723
8. On the Effect of the Voltaic Current on the Elimination of Sugar. By W. H. Stone, M.B., F.R.C.P. 724
9. On the Structure and Homologies of the Suspensory Ligament of the Fetlock in the Horse, Ass, Ox, Sheep, and Camel. By D. J. Cunningham, M.D., F.R.S.E. 726

Section E.—GEOGRAPHY.

THURSDAY, SEPTEMBER 1.

Address by Sir J. D. Hooker, K.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S., F.G.S., F.R.G.S., President of the Section 727

1. The Equipment of Exploring Expeditions Now and Fifty Years Ago. By Francis Galton, F.R.S. 738
2. Isochronic Postal Charts. By Francis Galton, F.R.S. 740
3. On the Geographical Work of the Palestine Exploration Fund. By Trelawney Saunders 741

FRIDAY, SEPTEMBER 2.

1. On the Progress of Geography in Asia during the last fifty years. By Sir Richard Temple, Bart., G.C.S.I., F.R.G.S. 741
2. On the Hot-lake District and the Glacier Scenery and Fjords of New Zealand. By Wm. Lant Carpenter, B.A., B.Sc., F.C.S. 742
3. On Oceanic or Maritime Discovery, Exploration, and Research. By Captain Sir F. J. Evans, R.N., K.C.B., F.R.S. 742
4. On the River Gambia. By R. E. Cole 742

MONDAY, SEPTEMBER 5.

1. On the Progress of Arctic Research since the Foundation of the British Association. By Clements R. Markham, C.B., F.R.S. 743
2. On the Commercial Importance of Hudson's Bay, with Remarks on recent Surveys and Investigations. By Robert Bell, M.D. 745

Page

3. On the Island of Socotra. By Professor BAYLEY BALFOUR, M.D.......... 746
4. A Journey to the Imperial Mausolea east of Peking. By F. S. A. BOURNE 746

TUESDAY, SEPTEMBER 6.

1. Comparative sketch of what was known in Africa in 1830 with what is known in 1881. By Lieut.-Colonel J. A. GRANT, C.B., F.R.S. 746
2. Some Results of Fifty Years' Exploration in Africa. By the Rev. HORACE WALLER........ 746
3. On a recent Visit to the Gold Mines of the West Coast of Africa. By Commander CAMERON, R.N. 747
4. An Account of a recent Visit to Dahomey. By the Rev. J. MILUM 747

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

THURSDAY, SEPTEMBER 1.

1. On Societies of Commercial Geography. By EDWARD J. WATHERSTON ... 748
2. Corn or Cattle: a Comparison of the Economic Results of Agriculture and Cattle-raising in relation to National Food-supply. By WILLIAM E. A. AXON, M.R.S.L., F.S.S. 749
3. Report of the Committee on the manner in which Rudimentary Science should be taught, and how Examinations should be held therein, in Elementary Schools........ 750
4. Agricultural Statistics and Prospects. By WM. BOTLY, M.R.A.S. 750
5. A General Banking Law for the United Kingdom. By WM. WESTGARTH 751

FRIDAY, SEPTEMBER 2.

Address by the Right Hon. M. E. GRANT DUFF, M.A., F.R.S., F.L.S., F.R.G.S., Governor of Madras, President of the Section 752

1. Notes on the Village System, and the Tenure of Land in the Dravidian Villages of the Dekhan. By Sir WALTER ELLIOT, K.C.S.I., F.R.S. 758
2. Report of the Anthropometric Committee 759
3. On the Relation of the Gold Standard in England to the International Money Market. By HYDE CLARKE, V.P.S.S. 759
4. The Silver Question, and the Double *versus* the Single Standard. By WM. WESTGARTH 759

SATURDAY, SEPTEMBER 3.

1. Results to be attained by applying to the Transfer of Land in this Country the methods employed in the British Colonies. By Sir ROBERT TORRENS, K.C.M.G........ 760
2. The Economic Influence of the Drinking Customs upon the Nation's Well-being. By WILLIAM HOYLE........ 760

MONDAY, SEPTEMBER 5.

1. Protection in Young Communities; Recorded Results in Victoria and New South Wales. By GEORGE BADEN-POWELL, M.A., F.R.A.S., F.S.S. 760

Page

2. Report of the Committee for inquiring into the present Appropriation of Wages and other sources of income, and considering how far it is consonant with the economic progress of the people of the United Kingdom... 761
3. On the Remedies proposed for Disputes about Wages. By the Rev. W. H. Jemison, LL.B. 761
4. The Depression in Agriculture; its Effects and its Lessons. By Henry F. Moore.... 761

TUESDAY, SEPTEMBER 6.

1. On the Free Public Libraries of Manchester and Notting Hill, London. By James Heywood, F.R.S. 762
2. On the Progress of British Commerce in a Generation. By E. J. Watherston 763
3. Some Results of the Removal of the Malt Tax. By H. Stopes.... 765
4. Bankruptcy in its Economic Bearings. By J. Macdonell 765
5. On Economics and Statistics, viewed from the standpoint of the Preliminary Sciences. By Patrick Geddes, F.R.S.E. 765

Section G.—MECHANICAL SCIENCE.

THURSDAY, SEPTEMBER 1.

Address by Sir W. Armstrong, C.B., D.C.L., LL.D., F.R.S., President of the Section 767

Observations on the Improvements of the Mississippi River, and on the proposed Ship Railway across the Isthmus of Tehuantepec, Mexico. By Captain J. B. Eads, C.E. 774

FRIDAY, SEPTEMBER 2.

1. Some of the Developments of Mechanical Engineering during the last half-century. By Sir F. J. Bramwell, M.I.C.E., F.R.S.... 774
2. On the Automatic Sounder. By James Dillon, M.I.C.E. 774
3. On the Economical Effect of using Cheap Gas for Gas-motors, with a description of Apparatus for producing such Gas. By J. Emerson Dowson, C.E. 775
4. On Continuous Door-locks and Footboards for Railway Carriages. By R. Pickwell.... 776
5. On a new Integrating Anemometer. By the Rev. J. M. Wilson, M.A., and H. S. Hele Shaw.... 776
6. The Advantages of Ex-focal Light in first-order Dioptric Lighthouses. By J. R. Wigham 776

MONDAY, SEPTEMBER 5.

1. On Telegraphic Photography. By Shelford Bidwell, M.A., LL.B..... 777
2. On the Swan Incandescent Lamp. By J. W. Swan 778
3. On Electric Lighting as applied to Coal Mines. By Andrew Jamieson... 778
4. On a Screw Gauge for Electrical Apparatus. By W. H. Preece, F.R.S. 779
5. On the Value of Quadriform Gaslights for Lighthouses in comparison with the Electric Light. By J. R. Wigham 779

TUESDAY, SEPTEMBER 6.

Page
1. Report of the Committee on Patent Legislation 779
2. Report of the Committee on the Steering of Screw Steamers 779
3. Report of the Committee on Wind Pressure 779
4 Report of the Committee on Tidal Observations in the English Channel and the North Sea 779
5. On some applications of Electric Energy to Horticultural and Agricultural Purposes. By Dr. C. Wm. Siemens, F.R.S. 779
6. On the Transmission of Power by Electricity. By J. N. Shoolbred, C.E., F.G.S. 779
7. On the Relative Value of Incandescent Electric Lights. By J. N. Shoolbred, C.E., F.G.S. 780
8. On the Society of Arts Patent Bill. By Sir F. J. Bramwell, M.I.C.E., F.R.S. 780

WEDNESDAY, SEPTEMBER 7.

1. On Coal and the Abatement of Smoke in Large Towns. By W. R. E. Coles 780
2. On British Shipping and the Tonnage Laws. By Captain Bedford Pim, R.N. 780
3. On the Pressure of Wind upon a Fixed Plane Surface. By Thomas Hawksley, C.E., F.R.S. 780
4. On a new form of Lightning Conductor, which can be easily tested. By Samuel Vyle 780
5. On an Organisation for the Systematic Gauging of the Wells, Springs, and Rivers of Great Britain. By Joseph Lucas, F.G.S. 781
6. On a Dynamometer Coupling. By Professors W. E. Ayrton, F.R.S., and John Perry, B.E. 781
7. On the Lawyer's Marine Pocket Case. By Captain Bedford Pim, R.N. 781

INDEX 783

LIST OF PLATES.

PLATES I. AND II.

Illustrative of the Report of the Committee on the Tertiary Flora of the North of Ireland.

PLATES III. AND IV.

Illustrative of the Report of the Anthropometric Committee.

PLATE V.

Illustrative of the Report of the Committee on the present state of our Knowledge of Spectrum Analysis.

PLATE VI.

Illustrative of the Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements.

PLATE VII.

Illustrative of Mr. G. M. WHIPPLE's Communication, 'Observations of Atmospheric Electricity at the Kew Observatory during 1880.'

PLATES VIII., IX., X., XI., XII., AND XIII.

Illustrative of Professor WILLIAM GRYLLS ADAMS's Communication, 'On Magnetic Disturbances and Earth-currents.'

PLATE XIV.

Illustrative of Dr. HUGGINS's Communication, 'On the Photographic Spectrum of Comet "b" 1881.'

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

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

RULES.

Admission of Members and Associates.

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

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

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

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

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

Compositions, Subscriptions, and Privileges.

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

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

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

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

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

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

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

   Annual Members *who have not intermitted* their Annual Subscription.
2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]
3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s*. 6*d*. per volume.[1]

Application to be made at the Office of the Association, 22 Albemarle Street, London, W.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

[1] A few complete sets, 1831 to 1874, are on sale, £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

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

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.

1. The President for the time being of any Scientific Society publishing Transactions or, in his absence, a delegate representing him; and the Secretary of such Society.[1] *Claims under this Rule to be sent to the Assistant Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

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

4. Vice-Presidents and Secretaries of Sections.

Organizing Sectional Committees.[2]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organizing Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[3] and of preparing Reports thereon, and on the order in which it is desirable that they should be

[1] Revised by the General Committee, Sheffield, 1879.

[2] Passed by the General Committee, Edinburgh, 1871.

[3] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be read, are now as far as possible determined by Organizing Committees for the several Sections *before the beginning of the Meeting.* It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each Author should prepare an Abstract of his Memoir, of a length suitable for insertion in the published Transactions of the Association,

read, to be presented to the Committees of the Sections at their first meeting. The Sectional Presidents of former years are *ex officio* members of the Organizing Sectional Committees.[1]

An Organizing Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to nominate the first members of the Sectional Committee, if they shall consider it expedient to do so, and to settle the terms of their report to the General Committee, after which their functions as an Organizing Committee shall cease.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day, in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday at 2 P.M., on the following Thursday, Friday, Saturday, Monday, and Tuesday, from 10 to 11 A.M., punctually, for the objects stated in the Rules of the Association, and specified below.

The business is to be conducted in the following manner:—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2. No paper shall be read until it has been formally accepted by the Committee of the Section, and entered on the minutes accordingly.
3. Papers which have been reported on unfavourably by the Organizing Committees shall not be brought before the Sectional Committees.[4]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis

and that he should send it, together with the original Memoir, by book-post, on or before............................, addressed thus—'General Secretaries, British Association, 22 Albemarle Street, London, W. For Section ....' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. a full three weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and Abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Assistant Secretary, *before the conclusion of the Meeting.*

[1] Added by the General Committee, Sheffield, 1879.
[2] Revised by the General Committee, Swansea, 1880.
[3] Passed by the General Committee, Edinburgh, 1871.
[4] These rules were adopted by the General Committee, Plymouth, 1877.

of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Transactions. He will next proceed to read the Report of the Organizing Committee.[1] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxvii), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and one of them appointed to act as Secretary, for insuring attention to business.*

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they

[1] This and the following sentence were added by the General Committee, 1871.

can be referred to the Committee of Recommendations or confirmed by the General Committee.

The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such Report has been received.[1]

Notices regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Individual or the Member first named of a Committee to whom a money grant has been made must (previously to the next Meeting of the Association) forward to the General Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one Meeting of the Association expire *a week before* the opening of the ensuing Meeting: nor is the Treasurer authorized, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Member first named is the only person entitled to call on the Treasurer, Professor A. W. Williamson, University College, London, W.C., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation from 10 to 11 daily. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At 11 precisely the Chair will be taken, and the reading of communications, in the order previously made public, commenced. At 3 P.M. the Sections will close.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

[1] Passed by the General Committee at Sheffield, 1879.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1.—To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.

2.—To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Assistant Secretary.

3.—Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed, during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

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

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

Local Committees.

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

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

Officers.

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

Council.

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

Papers and Communications.

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

Accounts.

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

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

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., 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, Esq., 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, Esq., 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, Esq., F.L.S., &c. Wm. Hutton, Esq., 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.	The Marquis of Northampton. The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., 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-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., 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, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The 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. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L. F.R.S., M.P. for the University of Oxford. OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University. Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's.	Matthew Moggridge, Esq. D. Nicol, Esq., 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. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews. EDINBURGH, July 21, 1850.	The 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. The 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. The 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.

PRESIDENTS.	VICE-PRESIDENTS	LOCAL SECRETARIES.
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, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., 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 Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mech nics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., 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, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., 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 Hugell, 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 Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.

HIS ROYAL HIGHNESS THE PRINCE CONSORT.. ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. .. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. ...... MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.

b 2

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford. BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hinds, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.

PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S. F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S. L. & E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Earl of Chichester, Lord-Lieutenant of the County of Sussex The Duke of Norfolk The Right Hon. the Duke of Richmond, K.G., P.C., D.C.L. The Right Hon. the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Professor Phillips, D.C.L., F.R.S., J. P. Gassiot, Esq., D.C.L., F.R.S. Sir John Hawkshaw, F.R.S., F.G.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	SECRETARIES.
SIR JOHN HAWKSHAW, C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S. L. & E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Sir William Thomson, M.A., LL.D., D.C.L., F.R.S. L. & E. Professor Allen Thomson, M.D., LL.D., F.R.S. L. & E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S. L. & E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S. L. & E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D, F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. Professor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries

MATHEMATICAL AND PHYSICAL SCIENCES.

COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.

Date and Place	Presidents	Secretaries
1832. Oxford......	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.

SECTION A.—MATHEMATICS AND PHYSICS.

Date and Place	Presidents	Secretaries
1835. Dublin......	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol......	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S............	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.........	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S., &c.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.........	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford	Rev. B. Price, M.A., F.R.S....	Rev. G C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S.	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. McAlister.
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. McAlister.
1881. York.........	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Prof. O. J. Lodge, D. McAlister, Rev. W. Routh.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

Date and Place	Presidents	Secretaries
1835. Dublin	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool	Michael Faraday, F.R.S.	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork	Prof. Apjohn, M.R.I.A.	R. Hunt, Dr. Sweeny.
1844. York	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S.	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford	Prof. B. C. Brodie, F.R.S.	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. A. Miller, M.D., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.

Date and Place	Presidents	Secretaries
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E., F.C.S.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S., F.C.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S., F.C.S. ...	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S., F.C.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S.	H. S. Bell, W. Chandler Roberts, J. M. Thomson.
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	H. B. Dixon, Dr. W. R. Eaton Hodgkinson, P. Phillips Bedson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, T. Gough.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geography*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography*, G.B.Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Captain H. M. Denham, R.N.
1838. Newcastle...	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhope.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*, G.B.Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton	Leonard Horner, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham.—*Geography*, Dr. C. T. Beke.

Date and Place	Presidents	Secretaries
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. D. C. L. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.

[1] At a meeting of the General Committee held in 1850, it was resolved 'That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section,"' for Presidents and Secretaries of which see page xlvii.

Date and Place	Presidents	Secretaries
1872. Brighton...	R. A. C. Godwin-Austen, F.R.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol......	Dr. Thomas Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. Martin Duncan, M.B., F.R.S., F.G.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, LL.D., F.R.S., F.G.S.	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham.....................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman...	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay..................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D.......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

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

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. xlvi.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. xlvi.

Date and Place	Presidents	Secretaries
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull.........	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.[1]

1866. Nottingham	Prof. Huxley, LL.D., F.R.S. —*Physiological Dep.*, Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.*, Alf. R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter......	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.

[1] At a meeting of the General Committee in 1865, it was resolved:—'That the title of Section D be changed to Biology;' and 'That for the word "Subsection," in the rules for conducting the business of the Sections, the word "Department" be substituted.'

Date and Place	Presidents	Secretaries
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.
1874. Belfast	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres.R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, M.D., F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, M.D., F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.R.G.S., F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, M.A., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick, F.R.S.E.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, LL.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister, M.D.—*Dep. of Anthropol.*, Francis Galton, M.A., F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S. —*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, M.D., F.R.S. —*Dep. of Anat. and Physiol.*, F. M. Balfour, M.A., F.R.S.—*Dep. of Anthropol.*, F. W. Rudler, F.G.S.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	Richard Owen, C.B., M.D., F.R.S.—*Dep. of Anthropol.*, Prof. W. H. Flower, LL.D., F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, M.D., F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

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

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

1835. Dublin	Dr. Pritchard........................	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.

Date and Place	Presidents	Secretaries
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.
1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844 York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.

SECTION E.—PHYSIOLOGY.

Date and Place	Presidents	Secretaries
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

Date and Place	Presidents	Secretaries
1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S.L.& E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	C. E. Paget, M.D...............	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.........	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birminghm.[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. xlii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

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

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull.........	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.

[1] By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. xliv). The Section being then vacant was assigned in 1851 to Geography.

[2] *Vide* note on page xlv.

Date and Place	Presidents	Secretaries
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S..........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S..........	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, C. R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter......	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	Clements R. Markham, A. Buchan, J. H. Thomas, A. Keith Johnston.
1872. Brighton ...	Francis Galton, F.R.S..........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol......	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. Oliphant Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B., F.R.S., F.R.G.S., F.R.A.S.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S. L. & E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.

Date and Place	Presidents	Secretaries

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

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

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S.	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull	James Heywood, M.P., F.R.S.	Edward Cheshire, Wm. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin......	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.

Date and Place	Presidents	Secretaries
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers............	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	Edmund Macrory, Frederick Purdy, Charles T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, Frank P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres.S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D., M.R.I.A.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York.........	Rt. Hon. M. E. Grant Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843 Cork	Prof. J. Macneill, M.R.I.A. ...	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford	Rev. Professor Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Professor Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.

Date and Place	Presidents	Secretaries
1849. Birmingham	Robert Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S..........	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, C.E., F.R.S.	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool...	John Scott Russell, F.R.S.	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine C.E., F.R.S.	L. Hill, jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, jun., H. M. Jeffery.
1857. Dublin......	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge	Wm. Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. A. Tarbottom.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S..........	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	James Abernethy, V.P. Inst. C.E., F.R.S.E.	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.

List of Evening Lectures.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S.	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy, F.R.S., Astron. Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy, F.R.S., Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.............	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.

Date and Place	Lecturer	Subject of Discourse
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G.B. Airy, F.R.S., Astron. Royal	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.............	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S.......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.........	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S............	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.........	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S. ...	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S.......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S....	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S................	Some recent investigations and applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilization.
1872. Brighton ...	Prof. P. Martin Duncan, M.D., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarized Light.
	F. J. Bramwell, F.R.S..........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The *Challenger* Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	The Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S............	The new Element, Gallium.

Date and Place	Lecturer	Subject of Discourse
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S..........	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S.	The Electric Discharge, its Forms and its Functions.

Lectures to the Operative Classes.

1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S.............	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B., R.N.	A Journey through Africa.
1877. Plymouth...	W. H. Preece......................	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York.........	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE YORK MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S.

Vice-Presidents.—Professor J. C. Adams, M.A., LL.D., F.R.S.; Professor Ball, LL.D., F.R.S.; Professor Cayley, LL.D., D.C.L., F.R.S.; Professor G. Carey Foster, F.R.S.; J. W. L Glaisher, M.A., F.R.S.; Rev. S. Haughton, M.D., F.R.S.; T. Archer Hirst, Ph.D., V.P.R.S.; Professor Bartholomew Price, M.A., F.R.S.; Professor H. J. S. Smith, M.A., F.R.S.; W. Spottiswoode, M.A., LL.D., Pres. R.S.

Secretaries.—Professor W. E. Ayrton, F.R.S.; Professor Oliver J. Lodge, D.Sc.; Donald McAlister, M.A., M.B., B.Sc. (*Recorder*); Rev. W. Routh, M.A.

SECTION B.—CHEMICAL SCIENCE.

President.—Professor A. W. Williamson, Ph.D., LL.D., F.R.S., V.P.C.S.

Vice-Presidents.—I. Lowthian Bell, F.R.S.; Professor J. Dewar, M.A., F.R.S.; Professor E. Frankland, D.C.L., F.R.S.; J. H. Gilbert, Ph.D., F.R.S.; J. H. Gladstone, Ph.D., F.R.S.; A. G. Vernon Harcourt, M.A., F.R.S.; Professor W. Odling, M.B., F.R.S.; Professor H. E. Roscoe, B.A., F.R.S.; Professor W. J. Russell, F.R.S.; Professor T. E. Thorpe, Ph.D., F.R.S.

Secretaries.—P. Phillips Bedson, D.Sc., F.C.S. (*Recorder*); Harold B. Dixon, M.A., F.C.S.; T. Gough, B.Sc., F.C.S.

SECTION C.—GEOLOGY.

President.—Andrew Crombie Ramsay, LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology.

Vice-Presidents.—Professor P. M. Duncan, M.B., F.R.S.; R. Etheridge, F.R.S.; J. Evans, D.C.L., F.R.S.; Professor E. Hull, LL.D., F.R.S.; W. Pengelly, F.R.S.; Professor J. Prestwich, M.A., F.R.S.; H. C. Sorby, LL.D., F.R.S.; Professor W. C. Williamson, F.R.S.; T. Wright, M.D., F.R.S.

Secretaries.—J. E. Clark, B.Sc., F.G.S.; W. Keeping, M.A., F.G.S.; W. Topley, F.G.S. (*Recorder*); W. Whitaker, B.A., F.G.S.

SECTION D.—BIOLOGY.

President.—Richard Owen, C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.Z.S.

Vice-Presidents.—Professor W. H. Flower, LL.D., F.R.S., F.R.C.S., F.L.S., F.G.S., Pres. Z.S.; Professor J. S. Burdon Sanderson, M.D., LL.D., F.R.S.; Professor Acland, M.D., F.R.S.; Professor Balfour, M.D., F.R.S.; J. Beddoe, M.D., F.R.S.; W. Bowman, M.D., F.R.S.; Professor Asa Gray; Professor Huxley, LL.D., Sec. R.S.; Professor A. Newton, F.R.S.; P. L. Sclater, Ph.D., F.R.S.

Secretaries.—G. W. Bloxam, M.A., F.L.S. (*Recorder*); W. A. Forbes, B.A., F.Z.S.; Rev. W. C. Hey, M.A.; Professor M'Nab, M.D. (*Recorder*); W. North, B.A., F.C.S.; John Priestley (*Recorder*); Howard Saunders, F.L.S., F.Z.S.; H. E. Spencer.

SECTION E.—GEOGRAPHY.

President.—Sir J. D. Hooker, K.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S., F.R.G.S.

Vice-Presidents.—Sir Alexander Armstrong, K.C.B., F.R.S.; Professor I. Bayley Balfour, D.Sc.; Francis Galton, M.A., F.R.S.; Clements R. Markham, C.B., F.R.S.; Admiral Sir E. Ommanney, C.B., F.R.S.; Sir Richard Temple, Bart., G.C.S.I.; Professor Sir Wyville Thomson, D.Sc., F.R.S.

Secretaries.—J. W. Barry; H. W. Bates, F.R.S., Assistant-Sec. R.G.S. (*Recorder*).

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—The Right Hon. M. E. Grant Duff, M.A., LL.B., F.R.S., F.L.S., F.R.G.S., Governor of Madras.

Vice-Presidents.—The Right Hon. the Lord Mayor of York; the Right Hon. Lord Houghton, M.A., D.C.L., F.R.S., F.R.G.S.; the Lord Reay; James Heywood, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S.

Secretaries.—Constantine Molloy (*Recorder*); W. W. Morrell; J. F. Moss.

SECTION G.—MECHANICAL SCIENCE.

President.—Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.

Vice-Presidents.—J. Abernethy, Pres. Inst. C.E.; W. H. Barlow, F.R.S.; J. F. Bateman, F.R.S.; Sir Henry Bessemer, F.R.S.; Sir Frederick Bramwell, F.R.S.; Captain James B. Eads, C.E.; Edward Easton, C.E.; T. Hawksley, F.R.S.; C. W. Siemens, D.C.L., LL.D., F.R.S.

Secretaries.—A. T. Atchison (*Recorder*); J. F. Stephenson; H. Trueman Wood.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from August 25, 1880 (commencement of Swansea Meeting), to August 31, 1881. Not including receipts at York Meeting.

1880–81. RECEIPTS.	£	s.	d.
By Balance of last Account, Swansea Meeting	503	5	5
Received for Life Compositions at Swansea Meeting and since	160	0	0
,, Annual Subscriptions ditto ditto	473	0	0
,, Associates' Tickets at Swansea Meeting	390	0	0
,, Ladies' Tickets ditto	147	0	0
,, Dividends on Stock	248	12	7
,, Sale of Publications	141	0	11
Received for Rent from Mathematical Society, year ending September 29, 1880	12	15	0
By return of the Grant made at Sheffield Meeting, 1879, 'Laws of Water Friction'	20	0	0
	£2095	13	11

1880–81. PAYMENTS.	£	s.	d.	£	s.	d.
By paid Expenses of Swansea Meeting, also Sundry Printing, Binding, Advertising, and Incidental Expenses				279	3	4
,, Messrs. Spottiswoode & Co.'s account for printing for the year 1880–81, Report of 50th Meeting, Vol. XLIX. (Sheffield)				664	9	0
,, Salaries (1 year)				470	0	0
,, Rent and Office Expenses (22 Albemarle Street—1 year)				117	0	0
,, Grants made at Swansea Meeting:—						
Lunar Disturbance of Gravity	30	0	0			
Underground Temperature	20	0	0			
High Insulation Key	5	0	0			
Tidal Observations	10	0	0			
Fossil Polyzoa	10	0	0			
Underground Waters	10	0	0			
Earthquakes in Japan	25	0	0			
Tertiary Flora	20	0	0			
Scottish Zoological Station	50	0	0			
Naples Zoological Station	75	0	0			
Natural History of Socotra	50	0	0			
Zoological Record	100	0	0			
Weights and Heights of Human Beings	30	0	0			
Electrical Standards	25	0	0			
Anthropological Notes and Queries	9	0	0			
Specific Refractions	7	3	1			
				476	3	1
Balance at Bank of England, Western Branch				88	18	6
				£2095	13	11

ALEX. W. WILLIAMSON.

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L.	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S.	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S.	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.......	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne ...	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S.	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne	The Duke of Northumberland	...	...
1839, Aug. 26 ...	Birmingham.........	The Rev. W. Vernon Harcourt	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton......	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D. ...	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.......	314	18
1848, Aug. 9 ...	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12 ...	Birmingham.........	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2 ...	Ipswich	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3 ...	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S. ...	194	33
1856, Aug. 6 ...	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds..................	Richard Owen, M.D., D.C.L...	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. the Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A. ...	286	21
1861, Sept. 4 ...	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1 ...	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6 ...	Birmingham.........	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18 ...	Exeter	Prof. G. G. Stokes, D.C.L........	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.......	314	39
1871, Aug. 2 ...	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14 ...	Brighton	Dr. W. B. Carpenter, F.R.S. ...	245	36
1873, Sept. 17 ...	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19 ...	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25 ...	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6 ...	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15 ...	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14 ...	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20 ...	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25 ...	Swansea	A. C. Ramsay, LL.D., F.R.S....	144	11
1881, Aug. 31 ...	York	Sir John Lubbock, Bart., F.R.S.	272	28

Annual Meetings of the Association.

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	£ s. d.	£ s. d.	
...	...	...	...	...	353	....	....	1831
...	...	...	...	...	...	....	....	1832
...	...	...	...	...	900	....	....	1833
...	...	...	...	...	1298	....	20 0 0	1834
...	...	...	...	...	...	....	167 0 0	1835
...	...	...	...	...	1350	....	435 0 0	1836
...	...	...	...	...	1840	....	922 12 6	1837
...	...	...	1100*	...	2400	....	932 2 2	1838
...	...	...	...	34	1438	....	1595 11 0	1839
...	...	...	...	40	1353	....	1546 16 4	1840
46	317	...	60*	...	891	....	1235 10 11	1841
75	376	33†	331*	28	1315	....	1449 17 8	1842
71	185	...	160	...	...	....	1565 10 2	1843
45	190	9†	260	...	...	....	981 12 8	1844
94	22	407	172	35	1079	....	831 9 9	1845
65	39	270	196	36	857	....	685 16 0	1846
197	40	495	203	53	1320	....	208 5 4	1847
54	25	376	197	15	819	707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 3 1	1881

* Ladies were not admitted by purchased Tickets until 1843.
Tickets of Admission to Sections only. ‡ Including Ladies.

OFFICERS AND COUNCIL, 1881–82.

PRESIDENT.

SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S.

VICE-PRESIDENTS.

His Grace the ARCHBISHOP OF YORK, D.D., F.R.S.
The Right Hon. the LORD MAYOR OF YORK.
The Right Hon. Lord HOUGHTON, M.A., D.C.L., F.R.S. F.R.G.S.
The Ven. Archdeacon CREYKE, M.A.
The Hon. Sir W. R. GROVE, M.A., D.C.L., F.R.S.
Professor G. G. STOKES, M.A., D.C.L., LL.D., Sec. R.S.
Sir JOHN HAWKSHAW, C.E., F.R.S., F.G.S., F.R.G.S.
ALLEN THOMSON, Esq., M.D., LL.D., F.R.S. L. & E.
Professor ALLMAN, M.D., LL.D., F.R.S. L. & E., F.L.S.

PRESIDENT ELECT.

C. W. SIEMENS, Esq., D.C.L., LL.D. F.R.S., F.C.S., M.I.C.E.

VICE-PRESIDENTS ELECT.

The Right Hon. the Lord MOUNT-TEMPLE.
Captain Sir F. J. EVANS, K.C.B., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty.
Colonel A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey.
WYNDHAM S. PORTAL, Esq.
Professor PRESTWICH, M.A., F.R.S., F.G.S., F.C.S.
F. A. ABEL, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department.
Professor DE CHAUMONT, M.D., F.R.S.
PHILIP LUTLEY SCLATER, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.

LOCAL SECRETARIES FOR THE MEETING AT SOUTHAMPTON.

C. W. A. JELLICOE, Esq. JOHN E. LE FEUVRE, Esq. MORRIS MILES, Esq.

LOCAL TREASURER FOR THE MEETING AT SOUTHAMPTON.

J. BLOUNT THOMAS, Esq.

ORDINARY MEMBERS OF THE COUNCIL.

ABEL, F. A., Esq., C.B., F.R.S.
ADAMS, Professor W. G., F.R.S.
BATEMAN, J. F., Esq., C.E., F.R.S.
CAYLEY, Professor, F.R.S.
DE LA RUE, WARREN, Esq., F.R.S.
EVANS, Captain Sir F. J., C.B., F.R.S.
EVANS, J., Esq., F.R.S.
FOSTER, Professor G. C., F.R.S.
GLAISHER, J. W. L., Esq., F.R.S.
HARCOURT, A. VERNON, Esq., F.R.S.
HASTINGS, G. W Esq., M.P.
HAWKSHAW, J. CLARKE, Esq., F.G.S.
HEYWOOD, J., Esq., F.R.S.
HUGGINS, W., Esq., F.R.S.
HUGHES, Professor T. McK., F.G.S.
JEFFREYS, J. GWYN, Esq., F.R.S.
NEWTON, Professor A., F.R.S.
PENGELLY, W., Esq., F.R.S.
PERKIN, W. H., Esq., F.R.S.
PITT-RIVERS, General A., F.R.S.
PRESTWICH, Professor, F.R.S.
RAYLEIGH, Lord, F.R.S.
SANDERSON, Prof. J. S. BURDON, F.R.S.
SORBY, Dr. H. C., F.R.S.
THUILLIER, Gen. Sir H. E. L., C.S.I., F.R.S.

GENERAL SECRETARIES.

Capt. DOUGLAS GALTON, C.B., D.C.L., F.R.S., F.G.S., 12 Chester Street, Grosvenor Place, London, S.W.
FRANCIS MAITLAND BALFOUR, Esq., M.A., LL.D., F.R.S., Trinity College, Cambridge.

SECRETARY.

Professor T. G. BONNEY, M.A., F.R.S., F.S.A., F.G.S., 22 Albemarle Street, London, W.

GENERAL TREASURER.

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

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, the President and President Elect, the Presidents of former years, the Vice-Presidents and Vice-Presidents Elect, the General and Assistant General Secretaries for the present and former years, the Secretary, the General Treasurers for the present and former years, and the Local Treasurer and Secretaries for the ensuing Meeting.

TRUSTEES (PERMANENT).

General Sir EDWARD SABINE, K.C.B., R.A., D.C.L., F.R.S.
Sir JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., Pres. R.S.

PRESIDENTS OF FORMER YEARS.

The Duke of Devonshire.
The Rev. T. R. Robinson, D.D.
Sir G. B. Airy.
General Sir E. Sabine, K.C.B.
The Earl of Harrowby.
The Duke of Argyll.
Richard Owen, M.D., D.C.L.
Sir W. G. Armstrong, C.B., LL.D.
Sir William R. Grove, F.R.S.
The Duke of Buccleuch, K.G.
Sir Joseph D. Hooker, D.C.L.
Prof. Stokes, M.A., D.C.L.
Prof. Huxley, LL.D., Sec. R.S.
Prof. Sir Wm. Thomson, D.C.L.
Dr. Carpenter, C.B., F.R.S.
Prof. Williamson, Ph.D., F.R.S.
Prof. Tyndall, D.C.L., F.R.S.
Sir John Hawkshaw, C.E., F.R.S.
Dr. T. Andrews, F.R.S.
Dr. Allen Thomson, F.R.S.
W. Spottiswoode, Esq., Pres. R.S.
Prof. Allman, M.D., F.R.S.
Sir A. C. Ramsay, LL.D., F.R.S.

GENERAL OFFICERS OF FORMER YEARS.

F. Galton, Esq., F.R.S.
Dr. T. A. Hirst, F.R.S.
Gen. Sir E. Sabine, K.C.B., F.R.S.
W. Spottiswoode, Esq., Pres. R.S.
Dr. Michael Foster, F.R.S.
George Griffith, Esq., M.A.
P. L. Sclater, Esq., F.R.S.

AUDITORS.

Dr. W. J. Russell, F.R.S. | Professor G. C. Foster, F.R.S.

REPORT OF THE COUNCIL.

Report of the Council for the year 1880–81, *presented to the General Committee at York, on Wednesday, August* 31, 1881.

The Council have received reports during the past year from the General Treasurer, and his account for the year will be laid before the General Committee this day. In consequence of the omission to appoint Auditors at the General Committee at Swansea, the accounts for the past year have been audited by Auditors nominated by the Council.

The Council have nominated the Lord Mayor of York, Lord Houghton, and the Ven. Archdeacon Creyke to be Vice-Presidents for the Meeting at York.

Mr. Sclater informed the Council in December last that he would not be able to hold the office of General Secretary after the York Meeting. The Council much regret the loss of Mr. Sclater's valuable services. They have resolved to recommend that Mr. F. M. Balfour, F.R.S., of Cambridge, be appointed one of the General Secretaries in the place of Mr. Sclater.

Towards the end of last year, the Council took into consideration the duties and position of the Assistant Secretary, and during the course of their deliberations Mr. Gordon tendered his resignation of the office. The Council, in accepting the resignation, resolved to continue his salary to the end of the financial year. In making arrangements to fill up the appointment, the Council further reconsidered the question of the position held by the Assistant Secretary. It will be in the recollection of the Committee that Mr. Gordon was appointed to a different position from that held by Professor Phillips and Mr. Griffith. The duties of the office were somewhat modified, and it was thought that by requiring more continuous attendance from the Assistant Secretary, it would be possible to dispense with the assistance of the clerk. The arrangement did not, however, answer the intended purpose; and the Council have resolved to nominate Professor Bonney, M.A., F.R.S., to fulfil the duties of the office of Assistant General Secretary, as defined by Professor Phillips in his memorandum dated May 3, 1861, with the title of Secretary, at a salary of 300*l.* per annum, with 25*l.* for travelling expenses.

The Council have to deplore the loss of Sir Philip de Malpas Grey Egerton, Bart., F.R.S., who had been a member of the Association since its commencement, and who held the office of Trustee for many years. The Council have nominated Mr. Spottiswoode as Trustee, in the place of Sir Philip Egerton.

Invitations for 1883 will be presented from Leicester, Southport, Oxford, Birmingham, Aberdeen, Nottingham; and an invitation to Worcester has been received for 1884.

The Council announce with great regret the loss that they have sustained during the past year by the death of Professor Rolleston, F.R.S. One vacancy having been thus caused in their body, there remain only four names which it is necessary to remove from the list.

The Council propose that, in accordance with the regulations, the four retiring members shall be the following:—

Mr. Easton.
Mr. Newmarch.
Prof. Roscoe.
Mr. Warington Smyth.

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

Abel, F. A., Esq., C.B., F.R.S.
Adams, Professor W. G., F.R.S.
Bateman, J. F., Esq., C.E., F.R.S.
Cayley, Professor, F.R.S.
*De La Rue, Warren, Esq., F.R.S.
Evans, Captain Sir F. J., C.B., F.R.S.
Evans, J., Esq., F.R.S.
Foster, Professor G. C., F.R.S.
Glaisher, J. W. L., Esq., F.R.S.
*Harcourt, A. Vernon, Esq., F.R.S.
*Hastings, G. W., Esq., M.P.
*Hawkshaw, J. C., Esq., F.G.S.
Heywood, J., Esq., F.R.S.
Huggins, W., Esq., F.R.S.
Hughes, Professor T. McK., M.A.
Jeffreys, J. Gwyn, Esq., F.R.S.
Newton, Professor A., F.R.S.
Pengelly, W., Esq., F.R.S.
Perkin, W. H., Esq., F.R.S.
Pitt-Rivers, General A., F.R.S.
*Prestwich, Prof., F.R.S.
Rayleigh, Lord, F.R.S.
Sanderson, Professor J. S. Burdon, F.R.S.
Sorby, Dr. H. C., F.R.S.
Thuillier, General Sir H. E. L., C.S.I., F.R.S.

Recommendations Adopted by the General Committee at the York Meeting in August and September, 1881.

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

Involving Grants of Money.

That the Council of the Association be requested to communicate with the President and Council of the Royal Geographical Society as to the complete Exploration of the Snowy Mountain District of Eastern Equatorial Africa, and be authorised to subscribe a sum of 100*l.* towards such exploration.

That Mr. G. H. Darwin, Sir William Thomson, Professor Tait, Professor Grant, Dr. Siemens, Professor Purser, Professor G. Forbes, and Mr. Horace Darwin be a Committee for the purpose of Measuring the Lunar Disturbance of Gravity; that Mr. G. H. Darwin be the Secretary, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Professor Schuster, Sir William Thomson, Professor H. E. Roscoe, Professor A. S. Herschel, Captain W. de W. Abney, Mr. R. H. Scott, and Dr. J. H. Gladstone be a Committee for the purpose of investigating the practicability of collecting and identifying Meteoric Dust, and of considering the question of undertaking regular observations in various localities; that Professor Schuster be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Professor Sylvester, Professor Cayley, and Professor Salmon be a Committee for the purpose of Calculating Tables of the Fundamental Invariants of Algebraic Forms; that Professor Sylvester be the Secretary, and that the sum of 80*l.* be placed at their disposal for the purpose.

That Mr. Robert H. Scott, Mr. J. Norman Lockyer, Professor H. J. S. Smith, Professor G. G. Stokes, Professor Balfour Stewart, and Mr. G. J. Symons be a Committee for the purpose of co-operating with the Meteorological Society of the Mauritius in their proposed publication of Daily Synoptic Charts of the Indian Ocean from the year 1861; that Mr. R. H. Scott be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Professor G. Carey Foster, Mr. C. Hockin, Sir William Thomson, Professor Ayrton, Mr. J. Perry, Professor W. G. Adams, Lord Rayleigh, Professor F. Jenkin, Dr. O. J. Lodge, Dr. John Hopkinson, Dr. A. Muirhead, and Mr. W. H. Preece be reappointed a Committee for the purpose of constructing and issuing practical Standards for use in Electrical Measurements; that the names of Mr. Herbert Taylor, Professor Everett, and Professor Schuster be added to the Committee; that Dr. A. Muirhead be the Secretary, and that the sum of 100*l*. be placed at their disposal for the purpose.

That Professor Dewar, Professor A. W. Williamson, Dr. Marshall Watts, Captain Abney, Mr. Stoney, Professor W. N. Hartley, Professor McLeod, Professor Carey Foster, Professor A. K. Huntington, Professor Emerson Reynolds, Professor Reinold, Professor Liveing, Lord Rayleigh, Professor Schuster, and Mr. W. Chandler Roberts be reappointed a Committee for the purpose of reporting upon the present state of our knowledge of Spectrum Analysis; that Mr. W. Chandler Roberts be the Secretary, and that the sum of 5*l*. be placed at their disposal for the purpose.

That Professors Balfour Stewart, Rücker, and T. E. Thorpe be a Committee for the purpose of reporting on the Methods employed in the Calibration of Mercurial Thermometers; that Professor Rücker be the Secretary, and that the sum of 20*l*. be placed at their disposal for the purpose.

That Professor Roscoe, Mr. Lockyer, Professor Dewar, Professor Liveing, Professor Schuster, Captain Abney, and Dr. Marshall Watts be a Committee for the purpose of preparing a new series of Wave-lengths Tables of the Spectra of the Elements; that Dr. Marshall Watts be the Secretary, and that the sum of 50*l*. be placed at their disposal for the purpose.

That Dr. Hugo Müller, Professors Williamson, Frankland, Roscoe, and Odling, and Mr. H. B. Dixon be a Committee for the purpose of drawing up in a tabular form the varieties of chemical names which have come into general use, for indicating the causes which have led to their adoption, and for considering what can be done to effect some convergence of the views on Chemical Nomenclature obtaining among English and foreign chemists; that Mr. H. B. Dixon be the Secretary, and that the sum of 10*l*. be placed at their disposal for the purpose.

That Professors Odling, Huntington, and Hartley be a Committee for the purpose of investigating by means of Photography the Ultra-Violet Spark Spectra emitted by Metallic Elements, and their combinations under varying conditions; that Professor W. N. Hartley be the Secretary, and that the sum of 25*l*. be placed at their disposal for the purpose.

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

That Professor A. C. Ramsay, Mr. Thomas Gray, and Professor John Milne be reappointed a Committee for the purpose of Investigating the Earthquake Phenomena of Japan; that Professor Milne be the Secretary, and that the sum of 25*l*. be placed at their disposal for the purpose.

That Dr. H. C. Sorby, Professor W. J. Sollas, and Professor William Ramsay be reappointed a Committee for the purpose of investigating the Conditions under which ordinary Sedimentary Materials may be converted into Metamorphic Rocks; that Professor Sollas be the Secretary, and that the sum of 10*l*. be placed at their disposal for the purpose.

That Professor W. C. Williamson and Mr. W. Cash be a committee for the purpose of investigating the Fossil Plants of Halifax; that Mr. W.

Cash be the Secretary, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Professor A. C. Ramsay, Professor J. Prestwich, Professor T. McK. Hughes, and Mr. W. Topley be a Committee for the purpose of assisting in the preparation of an International Geological Map of Europe; that Mr. W. Topley be the Secretary, and that the sum of 25*l.* be placed at their disposal for the purpose.

That Professor E. Hull, the Rev. H. W. Crosskey, Captain Douglas Galton, Professors G. A. Lebour and J. Prestwich, Messrs. James Glaisher, E. B. Marten, W. Molyneux, W. Pengelly, James Plant, James Parker, J. Roberts, S. Stooke, G. J. Symons, W. Whitaker, E. Wethered, and C. E. De Rance be a Committee for the purpose of investigating the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Waters supplied to various towns and districts from these formations; that Mr. C. E. De Rance be the Secretary, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Professor W. C. Williamson and Mr. W. H. Baily be reappointed a Committee for the purpose of Collecting and Reporting upon the Tertiary Flora of Beds associated with the Basalt of the North of Ireland; that Mr. Baily be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Dr. H. C. Sorby and Mr. G. R. Vine be a Committee for the purpose of reporting on the British Fossil Polyzoa; that Mr. Vine be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professor A. Leith Adams, Professor W. Boyd Dawkins, Dr. John Evans, Mr. G. H. Kinahan, and Mr. R. J. Ussher be reappointed a Committee for the purpose of carrying out Explorations in Caves in Carboniferous Limestone in the South of Ireland; that Mr. R. J. Ussher be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professor A. H. Green, Professor L. C. Miall, Mr. J. Brigg, and Mr. J. W. Davis be a Committee for the purpose of assisting in the Exploration of Raygill Fissure; that Mr. J. W. Davis be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Mr. F. M. Balfour, Professor Newton, Professor Huxley, Mr. Sclater, Professor Ray Lankester, Professor Allman, Dr. M. Foster, and Mr. P. Sladen be a Committee for the purpose of arranging for the Occupation of a Table at the Zoological Station at Naples; that Mr. P. Sladen be the Secretary, and that the sum of 80*l.* be placed at their disposal for the purpose.

That Dr. Burdon Sanderson, Dr. M. Foster, and Professor E. A. Schäfer, be a Committee for the purpose of investigating the Albuminoid Substances of Serum; that Professor E. A. Schäfer be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Dr. Pye-Smith, Dr. M. Foster, and Dr. Burdon Sanderson be reappointed a Committee for the purpose of investigating the Influence of Bodily Exercise on the Elimination of Nitrogen (the experiments to be conducted by Mr. North); that Dr. Burdon Sanderson be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose, the previous grant not having been expended.

That Dr. M. Foster, Dr. Pye-Smith, Professor Huxley, Dr. Carpenter, Dr. Gwyn Jeffreys, Mr. F. M. Balfour, Sir Wyville Thomson, Professor Lankester, Professor Allman, and Mr. P. Sladen, be a Committee for the purpose of aiding in the maintenance of the Scottish Zoological Station; that Mr. P. Sladen be the Secretary, and that the sum of 40*l.* be placed at their disposal for the purpose.

That Mr. J. Cordeaux, Mr. J. A. Harvie Brown, Professor Newton, Mr. R. M. Barrington, Mr. A. G. More, Mr. J. Hardy, and Mr. P. Kermode be a Committee for the purpose of obtaining (with the consent of the Master and Elder Brethren of the Trinity House and of the Commissioners of Northern Lights) observations on the Migrations of Birds at Lighthouses and Lightships, and of reporting upon the same at Southampton in 1882; that Mr. Cordeaux be the Secretary, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Lieut.-Colonel Godwin-Austen, Dr. G. Hartlaub, Sir J. Hooker, Dr. Günther, Mr. Seebohm, and Mr. Sclater be a Committee for the purpose of investigating the Natural History of Socotra and the adjacent Highlands of Arabia and Somali-land; that Mr. Sclater be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Mr. W. T. Thistleton-Dyer, Mr. Howard Saunders, and Mr. Sclater be a Committee for the purpose of investigating the Natural History of Timor-laut; that Mr. Thistleton-Dyer be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Mr. Stainton, Sir John Lubbock, and Mr. E. C. Rye be reappointed a Committee for the purpose of continuing a Record of Zoological Literature; that Mr. Stainton be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Professor Flower, Dr. Beddoe, Mr. F. Galton, Mr. Park Harrison, Dr. Muirhead, General Pitt-Rivers, Mr. F. W. Rudler, and Mr. C. Roberts be a Committee for the purpose of obtaining Photographs of the Typical Races composing the British Empire, with a view eventually to their publication; that Mr. Park Harrison be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Mr. F. Galton, Dr. Beddoe, Mr. Brabrook (Secretary and Reporter), Major-General Pitt-Rivers, Mr. J. P. Harrison, Mr. J. Heywood, Professor Leone Levi, Dr. F. H. Mahomed, Sir Rawson Rawson, and Mr. C. Roberts be a Committee for the purpose of carrying out the recommendations of the Anthropometric Committee of last year, especially as regards the Anthropometry of children and of females, and the more complete discussion of the collected facts; and that the sum of 50*l.* be placed at their disposal for the purpose.

Not Involving Grants of Money.

That Mr. W. Hicks be requested to continue his Report on Recent Progress in Hydrodynamics.

That Captain Abney, Professor W. G. Adams, Professor G. C. Foster, Lord Rayleigh, Mr. Preece, Professor Schuster, Professor Dewar, Professor Vernon Harcourt, and Professor Ayrton be a Committee for the purpose of fixing a Standard of White Light; and that Captain Abney be the Secretary.

That Sir William Thomson, Professor Tait, Dr. Siemens, Sir Frederick Bramwell, and Mr. J. T. Bottomley be a Committee for the purpose of continuing Secular Experiments on the Elasticity of Wires; and that Mr. Bottomley be the Secretary.

That Mr. Spottiswoode, Professor Stokes, Professor Cayley, Professor Smith, Sir William Thomson, Professor Henrici, Lord Rayleigh, and Mr. J. W. L. Glaisher be a Committee on Mathematical Notation and Printing; and that Mr. J. W. L. Glaisher be the Secretary.

That Professor Cayley, Professor Stokes, Professor H. J. S. Smith, Sir William Thomson, Mr. James Glaisher, and Mr. J. W. L. Glaisher be a Committee on Mathematical Tables; and that Mr. J. W. L. Glaisher be the Secretary.

That Professor W. E. Ayrton, Dr. O. J. Lodge, Mr. J. E. H. Gordon, and Mr. John Perry be a Committee for the purpose of actually measuring the specific inductive capacity of a good Sprengel Vacuum, and the specific resistance of gases at different pressures; and that Professor W. E. Ayrton be the Secretary.

That Professor Everett, Sir William Thomson, Mr. G. J. Symons, Professor Ramsay, Professor Geikie, Mr. J. Glaisher, Mr. Pengelly, Professor E. Hull, Dr. C. Le Neve Foster, Professor A. S. Herschel, Mr. G. A. Lebour, Mr. A. B. Wynne, Mr. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, and Mr. A. Strahan be a Committee for the purpose of making determinations of Underground Temperature; and that Professor Everett be the Secretary.

That Professor J. Prestwich, Professor T. McK. Hughes, Professor W. Boyd Dawkins, Professor T. G. Bonney, the Rev. H. W. Crosskey, Dr. Deane, and Messrs. C. E. De Rance, D. Mackintosh, R. H. Tiddeman, J. E. Lee, James Plant, W. Pengelly, W. Molyneux, H. G. Fordham, and W. Terrill be reappointed a Committee for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation; and that the Rev. H. W. Crosskey be the Secretary.

That Professor H. G. Seeley be requested to report on the Organisation of the Plesiosauria.

That Mr. C. E. De Rance, Sir John Hawkshaw, and Messrs. R. B. Grantham, J. B. Redman, W. Topley, J. W. Woodall, and W. Whitaker be a Committee for the purpose of inquiring into the rate of Erosion of the Sea-coasts of England and Wales, and the influence of the artificial abstraction of shingle and other material on that action; and that Mr. W. Topley be the Secretary.

That Mr. R. Meldola, General Pitt-Rivers, and Mr. Wm. Cole be a Committee for the purpose of investigating the ancient earthwork in Epping Forest known as Loughton Camp; and that Mr. W. Cole be the Secretary.

That Dr. Gwyn Jeffreys, Mr. Percy B. Sladen, and Sir Wyville Thomson be a Committee for the purpose of a Zoological Exploration of the Sea-bed lying north of the Hebrides; and that Dr. Gwyn Jeffreys be the Secretary.

That Mr. J. Glaisher, the Rev. Canon Tristram, and the Rev. F. Lawrence be a Committee for the purpose of promoting the survey of Eastern Palestine now on foot under the management of the Palestine Exploration Fund; and that Mr. J. Glaisher be the Secretary.

That Professor Leone Levi, Mr. Stephen Bourne, Dr. Hancock, Sir Antonio Brady, Professor Jevons, Mr. F. P. Fellows, Mr. E. J. Watherston, Mr. Pearson Hill, Mr. Geo. Baden Powell, and Mr. Jeremiah Head be reappointed a Committee for the purpose of continuing the inquiry into and completing the report upon the appropriation of wages and other sources of income, and considering how far it is consonant with the economic progress of the United Kingdom; and that Professor Leone Levi be the Secretary.

That the Committee on Science Teaching in Elementary Schools, consisting of Mr. James Heywood, Mr. Shaen, Mr. Stephen Bourne, Mr. Robert Wilkinson, the Rev. W. Delany, Professor Maskelyne, Dr. Silvanus P. Thompson, Miss Lydia E. Becker, Sir John Lubbock, Professor A. W. Williamson, Mrs. Augusta Webster, and Dr. Gladstone (Secretary), with power to add to their number, be reappointed for the ensuing year to watch and report on the workings of the proposed Revised New Code and of other legislation affecting the teaching of science in elementary schools.

That Sir Joseph Whitworth, Dr. Siemens, Sir F. J. Bramwell, Mr. A. Stroh, Mr. Beck, Mr. W. H. Preece, Mr. E. Crompton, Mr. E. Rigg, Mr. A. Le Neve Foster, Mr. Latimer Clark, Mr. H. Trueman Wood, and Mr. Buckney be a Committee for the purpose of determining a gauge for the manufacture of the various small screws used in Telegraphic and Electrical Apparatus, in Clockwork, and for other analogous purposes; and that Mr. H. Trueman Wood be the Secretary.

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

That the Committee, consisting of Mr. James Glaisher, Mr. C. W. Merrifield, Sir F. J. Bramwell, Professor O. Reynolds, Professor W. Cawthorne Unwin, Mr. Rogers Field, and Mr. A. T. Atchison be reappointed to consider and report upon the best means of ascertaining the effective Wind Pressures to which buildings and structures are exposed; and that Mr. A. T. Atchison be the Secretary.

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

Professor Halphen's paper, 'Sur les Séries Hypergéométriques,' and that of Professor Sturm, 'On some New Theorems on Curves of Double Curvature.'

Mr. Whipple's paper, 'On Observations of Atmospheric Electricity at the Kew Observatory during 1880.'

Professor Tyndall's paper 'On the Arrestation of Infusorial Life by Solar Light.'

Dr. S. Haughton's paper, 'On the Effects of Oceanic Currents upon Climates.'

Professor W. G. Adams's paper, 'On Magnetic Disturbances.'

Dr. C. W. Siemens' paper, 'On some Applications of Electric Energy to Horticulture and Agriculture.'

Professor Bayley Balfour's paper, 'On the Island of Socotra.'

Sir F. J. Bramwell's paper, 'On some of the Developments of Mechanical Engineering during the last half-century.'

Mr. T. Hawksley's paper, 'On the Pressure of Wind upon a Fixed Plane Surface.'

Resolutions referred to the Council for consideration.

That the Council be requested to consider the number and position of delegates from Scientific Societies, and the regulations which should be adopted for governing their relations to the Association.

That the Council be requested to consider how far it may be expedient to take steps to ascertain the feeling of foreign Scientific Associations as to the advisability of holding an International Scientific Congress.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the York Meeting in August and September 1881. *The Names of the Members who are entitled to call on the General Treasurer for the respective Grants are prefixed.*

	£	s.	d.
The Council.—Exploration of Mountain District of Eastern Equatorial Africa	100	0	0
Mathematics and Physics.			
*Darwin, Mr. G. H.—Lunar Disturbance of Gravity	15	0	0
Schuster, Dr. A.—Meteoric Dust	20	0	0
*Sylvester, Prof.—Fundamental Invariants (partly renewed)	80	0	0
Scott, Mr. R. H.—Synoptic Charts of the Indian Ocean ...	50	0	0
*Foster, Prof. G. C.—Standards for use in Electrical Measurements (partly renewed)	100	0	0
Chemistry.			
*Dewar, Prof.—Present state of knowledge of Spectrum Analysis	5	0	0
Stewart, Prof. Balfour.—Calibration of Mercurial Thermometers	20	0	0
Roscoe, Prof.—Wave-length Tables of Spectra of Elements	50	0	0
Müller, Dr. Hugo.—Chemical Nomenclature	10	0	0
Odling, Prof.—Photographing the Ultra-Violet Spark Spectra	25	0	0
Geology.			
*Evans, Dr. J.—Record of the Progress of Geology	100	0	0
*Ramsay, Prof.—Earthquake Phenomena of Japan	25	0	0
*Sorby, Dr. H. C.—Conditions of Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Williamson, Prof. W. C.—Fossil Plants of Halifax	15	0	0
Ramsay, Prof. A. C.—Geological Map of Europe	25	0	0
*Hull, Prof. E.—Circulation of Underground Waters	15	0	0
*Williamson, Prof. W. C.—Tertiary Flora associated with the Basalts of the North of Ireland	20	0	0
Carried forward	685	0	0

* Reappointed.

	£	s.	d.
Brought forward	685	0	0
*Sorby, Dr.—British Fossil Polyzoa	10	0	0
Adams, Prof. A. Leith.—Carboniferous Limestone Caves in South Ireland	10	0	0
Green, Prof.—Exploration of Raygill Fissure	20	0	0

Biology.

*Balfour, Mr. F. M.—Table at the Zoological Station at Naples	80	0	0
Sanderson, Dr. Burdon.—Albuminoid Substances of Serum	10	0	0
*Pye-Smith, Dr.—Influence of Bodily Exercise on the Elimination of Nitrogen	50	0	0
Foster, Dr. M.—Zoological Station in Scotland	40	0	0
*Cordeaux, Mr. J.—Migration of Birds	15	0	0
*Godwin-Austen, Lieut.-Col.—Natural History of Socotra	100	0	0
Thiselton-Dyer, Mr.—Natural History of Timor Laut	100	0	0
*Stainton, Mr.—Record of Zoological Literature	100	0	0
Flower, Prof.—Photographs of Typical Races	10	0	0

Statistics.

*Galton, Mr. F.—Anthropometry	50	0	0
	£1280	0	0

* Reappointed.

The Annual Meeting in 1882.

The Meeting at Southampton will commence on Wednesday, August 23, 1882.

Place of Meeting in 1883.

The Annual Meeting of the Association in 1883 will be held at Oxford.

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

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	171	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	166	16	6
Animal Secretions	10	10	0
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0

	£	s.	d.
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic 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
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	0
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	0	0
	£981	12	8

1845.

	£	s.	d.
Publications of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

	£	s.	d.
1848.			
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8
1849.			
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6
1850.			
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

	£	s.	d.
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855.			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4
1856.			
Maintaining the Establishment at Kew Observatory:— 1854.........£ 75 0 0; 1855.........£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0

	£	s.	d.
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4

1858.

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

1859.

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

1860.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0

	£	s.	d.
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
—— Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	20	0	0

	£	s.	d.
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-Beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyl and Methyl series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcon Quatries Fossils	20	0	0

	£	s.	d.
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-Beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-Embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-Lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-Lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions, &c.	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorological Research	100	0	0
Magnetization of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-Corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-Measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Eliptic Functions	100	0	0
Magnetization of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0

	£	s.	d.
Specific Volume of Liquids...	25	0	0
Estimation of Potash and Phosphoric Acid	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations ...	100	0	0
Kent's Cavern Exploration...	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record	100	0	0
Instructions for Travellers ...	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall	100	0	0
Ohm's Law	9	15	0
Tide Calculating Machine ...	200	0	0
Specific Volume of Liquids...	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate or Ethyl Sodaceto-acetate	5	0	0
Estimation of Potash and Phosphoric Acid	13	0	0
Exploration of Victoria Cave, Settle	100	0	0
Geological Record	100	0	0
Kent's Cavern Exploration...	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland	1	10	0
Zoological Record	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Zoological Station	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles	13	15	0
Measuring Speed of Ships ...	10	0	0
Effect of Propeller on turning of Steam Vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acids in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpæ, Report on	20	0	0
Mechanical Equivalent of Heat	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperatures	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	10	0	0
British Earthworks	25	0	0
Atmospheric Elasticity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid	1	18	0
Geological Record	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c.	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record	100	0	0
Investigation of Pulse Phenomena by means of Syphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters	15	0	0
Transmission of Electrical Impulses through Nerve Structure	30	0	0
Calculation of Factor Table of Fourth Million	100	0	0
Anthropometric Committee...	66	0	0
Chemical Composition and Structure of less known Alkaloids	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland ...	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0

	£	s.	d.
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Circulation of Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Co-efficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Co-efficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature	20	0	0
High Insulation Key	5	0	0
Tidal Observations	10	0	0
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station	50	0	0
Naples Zoological Station	75	0	0
Natural History of Socotra	50	0	0
Zoological Record	100	0	0
Weights and Heights of Human Beings	30	0	0
Electrical Standards	25	0	0
Anthropological Notes and Queries	9	0	0
Specific Refractions	7	3	1
	£476	3	1

General Meetings.

On Wednesday, August 31, at 8 P.M., in the Exhibition, Andrew Crombie Ramsay, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology, resigned the office of President to Sir John Lubbock, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S., who took the Chair, and delivered an Address, for which see page 1.

On Thursday, September 1, at 8 P.M., a Soirée took place in the Assembly and Concert Rooms.

On Friday, September 2, at 8.30 P.M., in the Exhibition, Professor Huxley, LL.D., Sec. R.S., delivered a Discourse on 'The Rise and Progress of Palæontology.'

On Monday, September 5, at 8.30 P.M., in the Exhibition, William Spottiswoode, Esq., M.A., D.C.L., LL.D., Pres. R.S., delivered a Discourse on 'The Electric Discharge, its Forms and its Functions.'

On Tuesday, September 6, at 8 P.M., a Soirée took place in the Exhibition.

On Wednesday, September 7, at 2.30 P.M., the concluding General Meeting took place in the Exhibition, 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 Southampton. [The Meeting is appointed to commence on Wednesday, August 23, 1882.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

SIR JOHN LUBBOCK, Bart., M.P.,

F.R.S., D.C.L., LL.D., Pres. Linn. Soc.,

PRESIDENT.

In the name of the British Association, which for the time I very unworthily represent, I beg to tender to you, my Lord Mayor, and through you to the City of York, our cordial thanks for your hospitable invitation and hearty welcome.

We feel, indeed, that in coming to York we are coming home. Gratefully as we acknowledge and much as we appreciate the kindness we have experienced elsewhere, and the friendly relations which exist between this Association and most—I might even say, all—our great cities, yet Sir R. Murchison truly observed at the close of our first meeting in 1831, that to York, 'as the cradle of the Association, we shall ever look back with gratitude; and whether we meet hereafter on the banks of the Isis, the Cam, or the Forth, to this spot we shall still fondly revert.' Indeed, it would have been a matter of much regret to all of us, if we had not been able on this, our fiftieth anniversary, to hold our meeting in our mother city.

My Lord Mayor, before going further, I must express my regret, especially when I call to mind the illustrious men who have preceded me in this chair, that it has not fallen to one of my eminent friends around me, to preside on this auspicious occasion. Conscious, however, as I am of my own deficiencies, I feel that I must not waste time in dwelling on them, more especially as in doing so I should but give them greater prominence. I will, therefore, only make one earnest appeal to your kind indulgence.

The connection of the British Association with the City of York does not depend merely on the fact that our first meeting was held here. It originated in a letter addressed by Sir D. Brewster to Professor Phillips, as Secretary to your York Philosophical Society, by whom the idea was warmly taken up. The first meeting was held on September 26, 1831, the chair being occupied by Lord Milton, who delivered an address, after which Mr. William Vernon Harcourt, Chairman of the Committee of Management, submitted to the meeting a code of rules which had been so maturely considered, and so wisely framed, that they have remained substantially the same down to the present day.

Of those who organised and took part in that first meeting, few, alas! remain. Brewster and Phillips, Harcourt and Lord Milton, Lyell and Murchison, all have passed away, but their memories live among us. Some few, indeed, of those present at our first meeting we rejoice to see here to-day, including one of the five members constituting the original organising Committee, our venerable Vice-President, Archdeacon Creyke.

The constitution and objects of the Association were so ably described by Mr. Spottiswoode, at Dublin, and are so well known to you, that I will not dwell on them this evening. The excellent President of the Royal Society, in the same address, suggested that the past history of the Association would form an appropriate theme for the present meeting. The history of the Association, however, is really the history of science, and I long shrank from the attempt to give even a panoramic survey of a subject so vast and so difficult; nor should I have ventured to make any such attempt, but that I knew I could rely on the assistance of friends in every department of science.

Certainly, however, this is an opportunity on which it may be well for us to consider what have been the principal scientific results of the last half-century, dwelling especially on those with which this Association is more directly concerned, either as being the work of our own members, or as having been made known at our meetings. I have, moreover, especially taken those discoveries which the Royal Society has deemed worthy of a medal. It is of course impossible within the limits of a single address to do more than allude to a few of these, and that very briefly. In dealing with so large a subject I first hoped that I might take our annual volumes as a text-book. This, however, I at once found to be quite impossible. For instance, the first volume commences with a Report on Astronomy by Sir G. Airy; I may be pardoned, I trust, for expressing my pleasure at finding that the second was one by my father, on the Tides, prepared like the preceding at the request of the Council, then comes one on Meteorology by Forbes, Radiant Heat by Baden Powell, Optics by Brewster, Mineralogy by Whewell, and so on. My best course will therefore be to take our different Sections one by one, and endeavour to bring before you a few of the principal results which have been obtained in each department.

The Biological Section is that with which I have been most intimately associated, and with which it is, perhaps, natural that I should begin.

Fifty years ago it was the general opinion that animals and plants came into existence just as we now see them. We took pleasure in their beauty; their adaptation to their habits and mode of life in many cases could not be overlooked or misunderstood. Nevertheless, the book of Nature was like some richly illuminated missal, written in an unknown tongue. The graceful forms of the letters, the beauty of the coloring, excited our wonder and admiration; but of the true meaning little was known to us; indeed we scarcely realised that there was any meaning to decipher. Now glimpses of the truth are gradually revealing themselves; we perceive that there is a reason—and in many cases we know what that reason is—for every difference in form, in size, and in color; for every bone and every feather, almost for every hair. Moreover, each problem which is solved opens out vistas, as it were, of others perhaps even more interesting. With this important change the name of our illustrious countryman, Darwin, is intimately associated, and the year 1859 will always be memorable in science as having produced his work on 'The Origin of Species.' In the previous year he and Wallace had published short papers, in which they clearly state the theory of natural selection, at which they had simultaneously and independently arrived. We cannot wonder that Darwin's views should have at first excited great opposition. Nevertheless from the first they met with powerful support, especially, in this country, from Hooker, Huxley, and Herbert Spencer. The theory is based on four axioms :—

'1. That no two animals or plants in nature are identical in all respects.

'2. That the offspring tend to inherit the peculiarities of their parents.

'3. That of those which come into existence, only a small number reach maturity.

'4. That those, which are, on the whole, best adapted to the circumstances in which they are placed, are most likely to leave descendants.'

Darwin commenced his work by discussing the causes and extent of variability in animals, and the origin of domestic varieties; he showed the impossibility of distinguishing between varieties and species, and pointed out the wide differences which man has produced in some cases—as, for instance, in our domestic pigeons, all unquestionably descended from a common stock. He dwelt on the struggle for existence (since become a household word), which, inevitably resulting in the survival of the fittest, tends gradually to adapt any race of animals to the conditions in which it occurs.

While thus, however, showing the great importance of natural selection, he attributed to it no exclusive influence, but fully admitted that other causes—the use and disuse of organs, sexual selection, &c.—had to be taken into consideration. Passing on to the difficulties of his theory he accounted for the absence of intermediate varieties between species, to a great extent, by the imperfection of the geological record. Here, however, I must observe that, as I have elsewhere remarked, those who rely on the absence of links between different species really argue in a vicious circle, because wherever such links do exist they regard the whole chain as a single species. The dog and jackal, for instance, are now regarded as two species, but if a series of links were discovered between them they would be united into one. Hence in this sense there never can be links between any two species, because as soon as the links are discovered the species are united. Every variable species consists, in fact, of a number of closely connected links.

But if the geological record be imperfect, it is still very instructive. The further palæontology has progressed, the more it has tended to fill up the gaps between existing groups and species: while the careful study of living forms has brought into prominence the variations dependent on food, climate, habitat, and other conditions, and shown that many species long supposed to be absolutely distinct are so closely linked together by intermediate forms that it is difficult to draw a satisfactory line between them. Thus the European and American bisons are connected by the Bison priscus of Prehistoric Europe; the grizzly bear and the brown bear, as Busk has shown, are apparently the modern representatives of the cave bear; Flower has pointed out the palæontological evidence of gradual modification of animal forms in the Artiodactyles; and we may almost say, as a general rule, that the earliest known mammalia belong to less specialised types than our existing species. They are not well-marked Carnivores, Rodents, Marsupials, &c., but rather constitute a group of generalised forms from which our present well-marked orders appear to have diverged. Among the Invertebrata, Carpenter and Williamson have proved that it is almost impossible to divide the Foraminifera into well-marked species; and, lastly, among plants, there are large genera, as, for instance, Rubus and Hieracium, with reference to the species of which no two botanists are agreed.

The principles of classification point also in the same direction, and are based more and more on the theory of descent. Biologists endeavour to arrange animals on what is called the 'natural system.' No one now places whales among fish, bats among birds, or shrews with mice, notwithstanding their external similarity; and Darwin maintained that 'community of descent was the hidden bond which naturalists had been unconsciously seeking.' How else, indeed, can we explain the fact that the framework of bones is so similar in the arm of a man, the wing of a bat, the fore-leg of a horse, and the fin of a porpoise—that the neck of a giraffe and that of an elephant contain the same number of vertebræ?

Strong evidence is, moreover, afforded by embryology; by the presence of rudimentary organs and transient characters, as, for instance, the existence in the calf of certain teeth which never cut the gums, the shrivelled and useless wings of some beetles, the presence of a series of arteries in the embryos of the higher Vertebrata exactly similar to those which supply the gills in fishes, even the spots on the young blackbird, the stripes on the lion's cub; these, and innumerable other facts of the same character, appear to be incompatible with the idea that each species was specially and independently created; and to prove, on the contrary, that the embryonic stages of species show us more or less clearly the structure of their ancestors.

Darwin's views, however, are still much misunderstood. I believe there are thousands who consider that according to his theory a sheep might turn into a cow, or a zebra into a horse. No one would more confidently withstand any such hypothesis, his view being, of course, not that the one could be changed into the other, but that both are descended from a common ancestor.

No one, at any rate, will question the immense impulse which Darwin has given to the study of natural history, the number of new views he has opened up, and the additional interest which he has aroused in, and contributed to, Biology. When we were young we knew that the leopard had spots, the tiger was striped, and the lion tawny; but why this was so it did not occur to us to ask; and if we had asked no one would have answered. Now we see at a glance that the stripes of the tiger have reference to its life among jungle-grasses; the lion is sandy, like the desert; while the markings of the leopard resemble spots of sunshine glancing through the leaves. Again, Wallace in his charming essays on natural selection has shown how the same philosophy may be applied even to birds' nests—how, for instance, open nests have led to the dull color of hen birds; the only British exception being the kingfisher, which, as we know, nests in river-banks. Lower still, among insects, Weismann has taught us that even the markings of caterpillars are full of interesting lessons; while, in other cases, specially among butterflies, Bates has made known to us the curious phenomena of mimicry.

The science of embryology may almost be said to have been created in the last half-century. Fifty years ago it was a very general opinion that animals which are unlike when mature, were dissimilar from the beginning. It is to Von Baer, the discoverer of the mammalian ovum, that we owe the great generalisation that the development of the egg is in the main a progress from the general to the special, that zoological affinity is the expression of similarity of development, and that the different great types of animal structure are the result of different modes of development—in fact, that embryology is the key to the laws of animal development.

Thus the young of existing species resemble in many cases the mature forms which flourished in ancient times. Huxley has traced up the genealogy of the horse to the Miocene Anchitherium, and his views have since been remarkably confirmed by Marsh's discovery of the Pliohippus, Protohippus, Miohippus, and Mesohippus, leading down from the Eohippus of the early tertiary strata. In the same way Boyd-Dawkins has called attention to the fact that just as the individual stag gradually acquires more and more complex antlers: having at first only a single prong, in the next year two points, in the following three, and so on; so the genus, as a whole, in Middle Miocene times, had two pronged horns; in the Upper

Miocene, three; and that it is not till the Upper Pliocene that we find any species with the magnificent antlers of our modern deer. It seems to be now generally admitted that birds have come down to us through the Dinosaurians, and, as Huxley as shown, the profound break once supposed to exist between birds and reptiles has been bridged over by the discovery of reptilian birds and bird-like reptiles; so that, in fact, birds are modified reptiles. Again, the remarkable genus Peripatus, so well studied by Moseley, tends to connect the annulose and articulate types.

Again, the structural resemblances between Amphioxus and the Ascidians had been pointed out by Goodsir; and Kowalevsky in 1866 showed that these were not mere analogies, but indicated a real affinity. These observations, in the words of Allen Thomson, 'have produced a change little short of revolutionary in embryological and zoological views, leading as they do to the support of the hypothesis that the Ascidian is an earlier stage in the phylogenetic history of the mammal and other vertebrates.'

The larval forms which occur in so many groups, and of which the Insects afford us the most familiar examples, are, in the words of Quatrefages, embryos, which lead an independent life. In such cases as these external conditions act upon the larvæ as they do upon the mature form; hence we have two classes of changes, adaptational or adaptive, and developmental. These and many other facts must be taken into consideration; nevertheless naturalists are now generally agreed that embryological characters are of high value as guides in classification, and it may, I think, be regarded as well-established that, just as the contents and sequence of rocks teach us the past history of the earth, so is the gradual development of the species indicated by the structure of the embryo and its developmental changes.

When the supporters of Darwin are told that his theory is incredible, they may fairly ask why it is impossible that a species in the course of hundreds of thousands of years should have passed through changes which occupy only a few days or weeks in the life-history of each individual?

The phenomena of yolk-segmentation, first observed by Prevost and Dumas, are now known to be, in some form or other, invariably the precursors of embryonic development; while they reproduce, as the first stages in the formation of the higher animals, the main and essential features in the life-history of the lowest forms. The 'blastoderm,' as it is called, or first germ of the embryo in the egg, divides itself into two layers, corresponding, as Huxley has shown, to the two layers into which the body of the Cœlenterata may be divided. Not only so, but most embryos at an early stage of development have the form of a cup, the walls of which are formed by the two layers of the blastoderm. Kowalevsky was the first to show the prevalence of this embryonic form, and subsequently Lankester and Hæckel put forward the hypothesis that it was the embryonic repetition of an ancestral type, from which all the higher forms are descended. The cavity of the cup is supposed to be the stomach of this simple organism, and the opening of the cup the mouth. The inner layer of the wall of the cup constitutes the digestive membrane, and the outer the skin. To this form Hæckel gave the name Gastræa. It is, perhaps, doubtful whether the theory of Lankester and Hæckel can be accepted in precisely the form they propounded it; but it has had an important influence on the progress of embryology. I cannot quit the science of embryology without alluding to the very admirable work on 'Comparative Embryology' by our new general secretary, Mr. Balfour, and also the 'Elements of Embryology' which he had previously published in conjunction with Dr. M. Foster.

In 1842, Steenstrup published his celebrated work on the 'Alternation of Generations,' in which he showed that many species are represented by two perfectly distinct types or broods, differing in form, structure, and habits; that in one of them males are entirely wanting, and that the reproduction is effected by fission, or by buds, which, however, are in some cases structurally indistinguishable from eggs. Steenstrup's illustrations were mainly taken from marine or parasitic species, of very great interest, but not generally familiar, excepting to naturalists. It has since been shown that the common Cynips or Gallfly is also a case in point. It had long been known that in some genera belonging to this group, males are entirely wanting, and it has now been shown by Bassett, and more thoroughly by Adler, that some of these species are double-brooded; the two broods having been considered as distinct genera.

Thus an insect known as Neuroterus lenticularis, of which females only occur, produces the familiar oak-spangles so common on the under sides of oak-leaves, from which emerge, not Neuroterus lenticularis, but an insect hitherto considered as a distinct species, belonging even to a different genus, Spathegaster baccarum. In Spathegaster both sexes occur; they produce the currant-like galls found on oaks, and from these galls Neuroterus is again developed. So also the King Charles oak-apples produce a species known as Teras terminalis, which descends to the ground, and makes small galls on the roots of the oak. From these emerge an insect known as Biorhiza aptera, which again gives rise to the common oak-apple.

Many butterflies, again, are dimorphic, existing under two, or even three, distinct forms—one that of the winter, the other of the summer brood or broods. Weismann has adduced strong reasons for thinking that during the glacial period these species were one-brooded only, and existed in the present winter form; that, as the climate improved, the period of warmth became sufficient to allow the development of a second brood, and led to the gradual rise of the summer form.

He and Edwards have shown that, while, by the application of cold, pupæ, which would naturally have produced the summer form, can be made to assume the winter dress; it is, on the contrary, far more difficult to change the winter into the summer colouring.

In some cases—as for instance in the very curious Leptodora crystallina (a fresh-water crustacean, inhabiting deep lakes and reservoirs, and which, as its name denotes, is almost perfectly transparent)—though the two forms are almost exactly similar in their mature state, the mode of development is very different; for, while the winter form goes through a well-marked metamorphosis, in the summer-brood the development is direct.

It might seem that such enquiries as these could hardly have any practical bearing. Yet it is not improbable that they may lead to very important results. For instance, it would appear that the fluke which produces the rot in sheep, passes one phase of its existence in snails or slugs, and we are not without hopes that the researches, in which our lamented friend Prof. Rolleston was engaged at the time of his death, and which Mr. Thomas is continuing, will lead, if not to the extirpation, at any rate to the diminution, of a pest from which our farmers have so grievously suffered.

It was in the year 1839 that Schwann and Schleiden demonstrated the intimate relation in which animals and plants stand to each other, by showing the identity of the laws of development of the elementary parts in the two kingdoms of organic nature. Analogies indeed had been previously pointed out, the presence of cellular tissue in certain parts of animals was known, but Caspar F. Wolff's brilliant memoir had been nearly forgotten; and the tendency of microscopical investigation had rather been to encourage the belief that no real similarity existed; that the cellular tissue of animals was essentially different from that of plants. This had arisen chiefly, perhaps, because fully formed tissues were compared, and it was mainly the study of the growth of cells which led to the demonstration of the general law of development for all organic elementary tissues.

As regards descriptive biology, by far the greater number of species now recorded have been named and described within the last half-century, and it is not too much to say that not a day passes without adding new species to our lists. A comparison, for instance, of the edition of Cuvier's 'Regne Animal,' published in 1828, as compared with the present state of our knowledge, is most striking.

Dr. Günther has been good enough to make a calculation for me. The numbers, of course, are only approximate, but it appears that while the total number of animals described up to 1831 was not more than 70,000, the number now is at least 320,000.

Lastly, to show how large a field still remains for exploration, I may add that Mr. Waterhouse assumes that our museums contain not fewer than 12,000 species of insects which have not yet been described, while our collections do not probably contain anything like one-half of those actually in existence. Further than this, the anatomy and habits even of those which have been described offer an inexhaustible field for research, and it is not going too far to say that there is not a single species which would not amply repay the devotion of a lifetime.

One remarkable feature in the modern progress of biological science has been the application of improved methods of observation and experiment; and the employment in physiological research of the exact measurements employed by the experimental physicist. Our microscopes have been greatly improved: achromatic object-glasses were introduced by Lister in 1829; the binocular arrangement by Wenham in 1856; while immersion lenses, first suggested by Amici, and since carried out under the formula of Abbe, are most valuable. The use of chemical re-agents in microscopical investigations has proved most instructive, and another very important method of investigation has been the power of obtaining very thin slices by imbedding the object to be examined in paraffin or some other soft substance. In this manner we can now obtain, say, fifty separate sections of the egg of a beetle, or the brain of a bee.

At the close of the last century, Sprengel published a most suggestive work on flowers, in which he pointed out the curious relation existing between these and insects, and showed that the latter carry the pollen from flower to flower. His observations, however, attracted little notice until Darwin called attention to the subject in 1862. It had long been known that the cowslip and primrose exist under two forms, about equally numerous, and differing from one another in the arrangements of their stamens and pistils; the one form having the stamens on the summit of the flower and the stigma half-way down; while in the other the relative positions are reversed, the stigma being at the summit of the tube and the stamens half-way down. This difference had, however, been regarded as a case of mere variability; but Darwin showed it to be a beautiful provision, the result of which is that insects fertilise each flower with pollen brought from a different plant; and he proved that flowers fertilised with pollen from the other form yield more seed than if fertilised with pollen of the same form, even if taken from a different plant.

Attention having been thus directed to the question an astonishing variety of most beautiful contrivances has been observed and described by many botanists, especially Hooker, Axel, Delpino, Hildebrand, Bennett, Fritz Müller, and above all Hermann Müller and Darwin himself. The general result is that to insects, and especially to bees, we owe the beauty of our gardens, the sweetness of our fields. To their beneficent, though unconscious action, flowers owe their scent and color, their honey—nay, in many cases, even their form. Their present shape and varied arrangements, their brilliant colors, their honey, and their sweet scent are all due to the selection exercised by insects.

In these cases the relation between plants and insects is one of mutual advantage. In many species, however, plants present us with complex arrangements adapted to protect them from insects; such, for instance, are in many cases the resinous glands which render leaves unpalatable; the thickets of hairs and other precautions which prevent flowers from being robbed of their honey by ants. Again, more than a century ago, our countryman, Ellis, described an American plant, Dionæa, in which the leaves are somewhat concave, with long lateral spines, and a joint in the middle, which closes up with a jerk, like a rat-trap, the moment any unwary insect alights on them. The plant, in fact, actually captures and devours insects. This observation also remained as an isolated fact until within the last few years, when Darwin, Hooker, and others have shown that many other species have curious and very varied contrivances for supplying themselves with animal food.

As regards the progress of botany in other directions, Mr. Thiselton Dyer has been kind enough to assist me in endeavouring to place the principal facts before you. Some of the most fascinating branches of botany —morphology, histology, and physiology scarcely existed before 1830. In the two former branches the discoveries of von Mohl are pre-eminent. He first observed cell-division in 1835, and detected the presence of starch in chlorophyll-corpuscles in 1837, while he first described protoplasm, now so familiar to us, at least by name, in 1846. In the same year Amici discovered the existence of the embryonic vesicle in the embryo sac, which develops into the embryo when fertilised by the entrance of the pollen-tube into the micropyle. The existence of sexual reproduction in the lower plants was doubtful, or at least doubted by some eminent authorities, as recently as 1853, when the actual process of fertilisation in the common bladderwrack of our shores was observed by Thuret, while the reproduction of the larger fungi was first worked out by De Bary in 1863.

As regards lichens, Schwendener proposed, in 1869, the startling theory, now however accepted by some of the highest authorities, that lichens are not autonomous organisms, but commensal associations of a fungus parasitic on an alga. With reference to the higher Cryptogams it is hardly too much to say that the whole of our exact knowledge of their life-history has been obtained during the last half-century. Thus in the case of ferns the male organs, or antheridia, were first discovered by Nägeli in 1844, and the archegonia, or female organs, by Suminski in 1848. The early stages in the development of mosses were worked out by Valentine in 1833. Lastly, the principle of Alternation of Generations in plants was discovered by Hofmeister. This eminent naturalist also, in 1851–4, pointed out the homologies of the reproductive processes in mosses, vascular cryptogams, gymnosperms, and angiosperms.

Geographical Botany can hardly be said to have had any scientific status anterior to the publication of the 'Origin of Species.' The way had been paved, however, by A. de Candolle and the well-known essay of Edward Forbes—'On the Distribution of the Plants and Animals of the British Isles,'—by Sir J. Hooker's introductory essay to the 'Flora of New Zealand,' and by Hooker and Thomson's introductory essay to the 'Flora Indica.' One result of these researches has been to give the *coup-de-grâce* to the theory of an Atlantis. Lastly, in a lecture delivered to the Geographical Society in 1878, Thiselton Dyer himself has summed up the present state of the subject, and contributed an important addition to our knowledge of plant-distribution by showing how its main features may be explained by migration in latitude from north to south without recourse being had to a submerged southern continent for explaining the features common to South Africa, Australia, and America.

The fact that systematic and geographical botany have claimed a preponderating share of the attention of British phytologists, is no doubt in great measure due to the ever-expanding area of the British Empire, and the rich botanical treasures which we are continually receiving from India and our numerous colonies. The series of Indian and Colonial Floras, published under the direction of the authorities at Kew, and the 'Genera Plantarum' of Bentham and Hooker, are certainly an honor to our country. To similar causes we may trace the rise and rapid progress of economic botany, to which the late Sir W. Hooker so greatly contributed.

In vegetable physiology some of the most striking researches have been on the effect produced by rays of light of different refrangibility. Daubeny, Draper, and Sachs have shown that the light of the red end of the spectrum is more effective than that of the blue, so far as the decomposition of carbon dioxide (carbonic acid) is concerned.

Nothing could have appeared less likely than that researches into the theory of spontaneous generation should have led to practical improvements in medical science. Yet such has been the case. Only a few years ago Bacteria seemed mere scientific curiosities. It had long been known that an infusion—say, of hay—would, if exposed to the atmosphere, be found, after a certain time, to teem with living forms. Even those few who still believe that life would be spontaneously generated in such an infusion, will admit that these minute organisms are, if not entirely, yet mainly, derived from germs floating in our atmosphere; and if precautions are taken to exclude such germs, as in the careful experiments especially of Pasteur, Tyndall, and Roberts, everyone will grant that in ninety-nine cases out of a hundred no such development of life will take place. In 1836–7 Cagniard de la Tour and Schwann independently showed that fermentation was no mere chemical process, but was due to the presence of a microscopic plant. But, more than this, it has been gradually established that putrefaction is also the work of microscopic organisms. Thirty years, however, elapsed before these important discoveries received any practical application.

At length, however, they have led to most important results in Surgery. One reason why compound fractures are so dangerous is because, the skin being broken, the air obtains access to the wound, bringing with it innumerable germs, which too often set up putrefying action. Lister first made a practical application of these observations. He set himself to find some substance capable of killing the germs without being itself too potent a caustic, and he found that dilute carbolic acid fulfilled these conditions. This discovery has enabled many operations to be performed which would previously have been almost hopeless.

The same idea seems destined to prove as useful in Medicine as in Surgery. There is great reason to suppose that many diseases, especially those of a zymotic character, have their origin in the germs of special organisms. We know that fevers run a certain definite course. The parasitic organisms are at first few, but gradually multiply at the expense of the patient, and then die out again. Indeed, it seems to be thoroughly established that many diseases are due to the excessive multiplication of microscopic organisms, and we are not without hope that means will be discovered by which, without injury to the patient, these terrible, though minute, enemies may be destroyed, and the disease thus stayed. Bacillus anthracis, for instance, is now known to be the cause of splenic fever, which is so fatal to cattle, and is also communicable to man. At Bradford, for instance, it is only too well known as the woolsorter's disease. If, however, matter containing the Bacillus be treated in a particular manner, and cattle be then inoculated with it, they are found to acquire an immunity from the fever. The interesting researches of Burdon Sanderson, Greenfield, Koch, Pasteur, Toussaint, and others, seem to justify the hope that we may be able to modify these and other germs, and then by appropriate inoculation to protect ourselves against fever and other acute diseases.

Ferrier's researches, in continuation of those of Fritsch and Hitzig, have enabled us to localize the function of various parts of the brain. His results have not only proved of great importance in surgery, and in many cases led to successful operations, by pointing out the exact source of the mischief, but an exact knowledge of the brain is also of the greatest importance in the treatment of nervous diseases. Echeverria has collected 165 cases of traumatic epilepsy, of which 64 per cent. were cured by removing a portion of the skull, the site for the operation and the exact nature of the lesion being indicated by cerebral localization.

The history of Anæsthetics is a most remarkable illustration how long we may be on the very verge of a most important discovery. Ether, which, as we all know, produces perfect insensibility to pain, was discovered as long ago as 1540. The anæsthetic property of nitrous oxide, now so extensively used, was observed in 1800 by Sir H. Davy, who actually experimented on himself, and had one of his teeth painlessly extracted when under its influence. He even suggests that 'as nitrous oxide gas seems capable of destroying pain, it could probably be used with advantage in surgical operations.' Nay, this property of nitrous oxide was habitually explained and illustrated in the chemical lectures given in hospitals, and yet for fifty years the gas was never used in actual operations. No one did more to promote the use of anæsthetics than Sir James Y. Simpson, who introduced chloroform, a substance which was discovered in 1831, and which for a while almost entirely superseded ether and nitrous oxide, though, with improved methods of administration, the latter are now coming into favour again.

The only other reference to Physiology which time permits me to make, is the great discovery of the reflex action, as it is called, of the nervous centres. Reflex actions had been long ago observed, and it had been shown by Whytt and Hales that they were more or less independent of volition. But the general opinion was that these movements indicated some feeble power of sensation independently of the brain, and it was not till the year 1832 that the 'reflex action' of certain nervous centres was made known to us by Marshall Hall, and almost at the same period by Johannes Müller.

Few branches of science have made more rapid progress in the last half-century than that which deals with the ancient condition of Man. When our Association was founded it was generally considered that the human race suddenly appeared on the scene, about 6,000 years ago, after the disappearance of the extinct mammalia, and when Europe, both as regards physical conditions and the other animals by which it was inhabited, was pretty much in the same state as in the period covered by Greek and Roman history. Since then the persevering researches of Layard, Rawlinson, Botta and others have made known to us, not only the statues and palaces of the ancient Assyrian monarchs, but even their libraries; the cuneiform characters have been deciphered, and we can not only see, but read, in the British Museum, the actual contemporary records, on burnt clay cylinders, of the events recorded in the historical books of the Old Testament and in the pages of Herodotus. The researches in Egypt also seem to have satisfactorily established the fact that the pyramids themselves are at least 6,000 years old, while it is obvious that the Assyrian and Egyptian monarchies cannot suddenly have attained to the wealth and power, the state of social organisation, and progress in the arts, of which we have before us, preserved by the sand of the desert from the ravages of man, such wonderful proofs.

In Europe, the writings of the earliest historians and poets indicated that, before iron came into general use, there was a time when bronze was the ordinary material of weapons, axes, and other cutting implements, and though it seemed *à priori* improbable that a compound of copper and tin should have preceded the simple metal iron, nevertheless the researches of archæologists have shown that there really was in Europe a 'Bronze Age,' which at the dawn of history was just giving way to that of 'Iron.'

The contents of ancient graves, buried in many cases so that their owner might carry some at least of his wealth with him to the world of spirits, have proved very instructive. More especially the results obtained by Nilsson in Scandinavia, by Hoare and Borlase, Bateman, Greenwell, and Pitt-Rivers, in our own country, and the contents of the rich cemetery at Hallstadt, left no room for doubt as to the existence of a Bronze Age; but we get a completer idea of the condition of Man at this period from the Swiss lake-villages, first made known to us by Keller, and subsequently studied by Morlot, Troyon, Desor, Rütimeyer, Heer, and other Swiss archæologists. Along the shallow edges of the Swiss lakes there flourished, once upon a time, many populous villages or towns, built on platforms supported by piles, exactly as many Malayan villages are now. Under these circumstances innumerable objects were one by one dropped into the water; sometimes whole villages were burnt, and their contents submerged; and thus we have been able to recover, from the waters of oblivion in which they had rested for more than 2,000 years, not only the arms and tools of this ancient people, the bones of their animals, their pottery and ornaments, but the stuffs they wore, the grain they had stored up for future use, even fruits and cakes of bread.

But this bronze-using people were not the earliest occupants of Europe. The contents of ancient tombs give evidence of a time when metal was unknown. This also was confirmed by the evidence then unexpectedly received from the Swiss lakes.* By the side of the bronze-age villages were others, not less extensive, in which, while implements of stone and bone were discovered literally by thousands, not a trace of metal was met with. The shell-mounds or refuse-heaps accumulated by the ancient fishermen along the shores of Denmark, and carefully examined by Steenstrup, Worsaae, and other Danish naturalists, fully confirmed the existence of a 'Stone Age.'

We have still much to learn, I need hardly say, about this Stone-age people, but it is surprising how much has been made out. Evans truly observes, in his admirable work on 'Ancient Stone Implements,' 'that so far as external appliances are concerned, they are almost as fully represented as would be those of any existing savage nation by the researches of a painstaking traveller.' We have their axes, adzes, chisels, borers, scrapers, and various other tools, and we know how they made and how they used them; we have their personal ornaments and implements of war; we have their cooking utensils; we know what they ate and what they wore; lastly, we know their mode of sepulture and funeral customs. They hunted the deer and horse, the bison and urus, the bear and the wolf, but the reindeer had already retreated to the North.

No bones of the reindeer, no fragment of any of the extinct mammalia, have been found in any of the Swiss lake-villages or in any of the thousands of tumuli which have been opened in our own country or in Central and Southern Europe. Yet the contents of caves and of river-gravels afford abundant evidence that there was a time when the mammoth and rhinoceros, the musk-ox and reindeer, the cave lion and hyena, the great bear and the gigantic Irish elk wandered in our woods and valleys, and the hippopotamus floated in our rivers; when England and France were united, and the Thames and the Rhine had a common estuary. This was long supposed to be before the advent of man. At length, however, the discoveries of Boucher de Perthes in the valley of the Somme, supported as they are by the researches of many continental naturalists, and in our own country of MacEnery and Godwin-Austen, Prestwich and Lyell, Vivian and Pengelly, Christy, Evans and many more, have proved that man formed a humble part of this strange assembly.

Nay, even at this early period there were at least two distinct races of men in Europe; one of them—as Boyd Dawkins has pointed out—closely resembling the modern Esquimaux in form, in his weapons and implements, probably in his clothing, as well as in so many of the animals with which he was associated.

At this stage Man appears to have been ignorant of pottery, to have had no knowledge of agriculture, no domestic animals, except perhaps the dog. His weapons were the axe, the spear, and the javelin; I do not believe he knew the use of the bow, though he was probably acquainted with the lance. He was, of course, ignorant of metal, and his stone implements, though skilfully formed, were of quite different shapes from those of the second Stone age, and were never ground. This earlier Stone period, when man co-existed with these extinct mammalia, is known as the Palæolithic, or Early Stone Age, in opposition to the Neolithic, or Newer Stone Age.

The remains of the mammalia which co-existed with man in prehistoric times have been most carefully studied by Owen, Lartet, Rütimeyer, Falconer, Busk, Boyd-Dawkins, and others. The presence of the mammoth, the reindeer, and especially of the musk-ox, indicates a severe, not to say an arctic, climate—the existence of which, moreover, was proved by other considerations; while, on the contrary, the hippopotamus requires considerable warmth. How then is this association to be explained?

While the climate of the globe is, no doubt, much affected by geographical conditions, the cold of the glacial period was, I believe, mainly due to the greater excentricity of the earth's orbit combined with the effects of precession of the ecliptic. The result of the latter condition is a period of 21,000 years, during one half of which the northern hemisphere is warmer than the southern, while during the other 10,500 years the reverse is the case. At present we are in the former phase, and there is, we know, a vast accumulation of ice at the south pole. But when the earth's orbit is nearly circular, as it is at present, the difference between the two hemispheres is not very great; while, on the contrary, as the excentricity of the orbit increases, the contrast between them increases also. This excentricity is continually oscillating within certain limits, which Croll and subsequently Stone have calculated for the last million years. At present the excentricity is ·016 and the mean temperature of the coldest month in London is about 40°. Such has been the state of things for nearly 100,000 years; but before that there was a period, beginning 300,000 years ago, when the excentricity of the orbit varied from ·26 to ·57. The result of this would be greatly to increase the effect due to the obliquity of the orbit; at certain periods the climate would be much warmer than at present, while at others the number of days in winter would be twenty more, and of summer twenty less, than now, while the mean temperature of the coldest month would be lowered 20°. We thus get something like a date for the last glacial epoch, and we see that it was not simply a period of cold, but rather one of extremes, each beat of the pendulum of temperature lasting for no less than 21,000 years. This explains the fact that, as Morlot showed in 1854, the glacial deposits of Switzerland, and, as we now know, those of Scotland, are not a single uniform layer, but a succession of strata indicating very different conditions. I agree also with Croll and Geikie in thinking that these considerations explain the apparent anomaly of the co-existence in the same gravels of arctic and tropical animals; the former having lived in the cold, while the latter flourished in the hot, periods.

It is, I think, now well established that man inhabited Europe during the milder periods of the glacial epoch. Some high authorities indeed consider that we have evidence of his presence in pre-glacial and even in Miocene times, but I confess that I am not satisfied on this point. Even the more recent period carries back the record of man's existence to a distance so great as altogether to change our views of ancient history.

Nor is it only as regards the antiquity and material condition of man in prehistoric times that great progress has been made. If time permitted I should have been glad to have dwelt on the origin and development of language, of custom, and of law. On all of these the comparison of the various lower races still inhabiting so large a portion of the earth's surface, has thrown much light; while even in the most cultivated nations we find survivals, curious fancies, and lingering ideas; the fossil remains as it were of former customs and religions, embedded in our modern civilisation, like the relics of extinct animals in the crust of the earth.

In geology the formation of our Association coincided with the appearance of Lyell's 'Principles of Geology,' the first volume of which was published in 1830 and the second in 1832. At that time the received opinion was that the phenomena of Geology could only be explained by violent periodical convulsions, and a high intensity of terrestrial energy culminating in repeated catastrophes. Hutton and Playfair had indeed maintained that such causes as those now in operation, would, if only time enough were allowed, account for the geological structure of the earth; nevertheless the opposite view generally prevailed, until Lyell, with rare sagacity and great eloquence, with a wealth of illustration and most powerful reasoning, convinced geologists that the forces now in action are powerful enough, if only time be given, to produce results quite as stupendous as those which Science records.

As regards stratigraphical geology, at the time of the first meeting of the British Association at York, the strata between the carboniferous limestone and the chalk had been mainly reduced to order and classified, chiefly through the labours of William Smith. But the classification of all the strata lying above the chalk and below the carboniferous limestone respectively, remained in a state of the greatest confusion. The year 1831 marks the period of the commencement of the joint labours of Sedgwick and Murchison, which resulted in the establishment of the Cambrian, Silurian, and Devonian systems. Our Pre-Cambrian strata have recently been divided by Hicks into four great groups of immense thickness, and implying a great lapse of time; but no fossils have yet been discovered in them. Lyell's classification of the Tertiary deposits; the result of the studies which he carried on with the assistance of Deshayes and others, was published in the third volume of the 'Principles of Geology' in 1833. The establishment of Lyell's divisions of Eocene, Miocene, and Pliocene, was the starting-point of a most important series of investigations by Prestwich and others of these younger deposits; as well as of the post-tertiary, quaternary, or drift beds, which are of special interest from the light they have thrown on the early history of man.

A full and admirable account of what has recently been accomplished in this department of science, especially as regards the palæozoic rocks, will be found in Etheridge's late address to the Geological Society.

The thickness of the sedimentary strata implies an enormous lapse of time, but the amount of subsequent destruction which has taken place is scarcely less surprising. Ramsay, for instance, has shown that in Wales from 9,000 to 11,000 feet of solid rock have been removed from large tracts of country. Faults or cracks there extend for miles, with the strata on one side raised in some cases as much as 10,000 feet above the same strata on the other, and yet there is not on the surface the slightest vestige of this gigantic dislocation.

The long lines of escarpment again, which stretch for miles across our country, and were long supposed to be ancient coast lines, are now ascertained, mainly through the researches of Whitaker, to be due to the differential action of aerial causes.

Before 1831 the only geological maps of this country were William Smith's general and county maps, published between the years 1815 and 1824. In the year 1832 De la Beche made proposals to the Board of Ordnance to color the ordnance-maps geologically, and a sum of 300*l.* was granted for the purpose. Out of this small beginning grew the important work of the Geological Survey.

The cause of slaty cleavage had long been one of the great difficulties of geology. Sedgwick suggested that it was produced by the action of crystalline or polar forces. According to this view miles and miles of country, comprising great mountain masses, were neither more nor less than parts of a gigantic crystal. Sharpe, however, called attention to the fact that shells and other fossils contained in slate rocks are compressed in a direction at right angles to the planes of cleavage, as if the rocks had been seized in the jaws of a gigantic vice. Sorby first maintained that the cleavage itself was due to pressure. He observed slate rocks containing small plates of mica, and that the effect of pressure would tend to arrange these plates with their flat surfaces perpendicular to the direction of the pressure. Tyndall has since shown that the presence of flat flakes is not necessary. He proved by experiment that pure wax could be made by pressure to split into plates of great tenuity, which he attributes mainly to the lateral sliding of the particles of the wax over each other; and thus the result of pressure on such a mass is to develop a fissile structure similar to that produced in wax on a small scale, or on a great one in the slate rocks of Cumberland or Wales.

The difficult problem of the conditions under which granite and certain other rocks were formed was attacked by Sorby with great skill in a paper read before the Geological Society in 1858. The microscopic hollows in many minerals contain a liquid which does not entirely fill the hollow, but leaves a small vacuum; and Sorby ingeniously pointed out that the rock must have solidified at least at a temperature high enough to expand the liquid so as to fill the cavity. Sorby's important memoir laid the foundation of microscopic petrography, which is now not only one of the most promising branches of geological research, but which has been successfully applied by Sorby himself, and by Maskelyne, to the study of meteorites.

As regards the physical character of the earth, two theories have been held: one, that of a fluid interior covered by a thin crust; the other, of a practically solid sphere. The former is now generally considered by physicists to be untenable. Though there is still much difference of opinion, the prevailing feeling on the subject has been expressed by Professor Le Conte, who says, 'the whole theory of igneous agencies—which is little less than the whole foundation of theoretic geology—must be reconstructed on the basis of a solid earth.'

In 1837 Agassiz startled the scientific world by his 'Discours sur l'ancienne extension des Glaciers,' in which, developing the observation already made by Charpentier and Venetz, that boulders had been transported to great distances, and that rocks far away from, or high above, existing glaciers, are polished and scratched by the action of ice, he boldly asserted the existence of a 'glacial period,' during which Switzerland and the North of Europe were subjected to great cold and buried under a vast sheet of ice.

The ancient poets described certain gifted mortals as privileged to descend into the interior of the earth, and have exercised their imagination in recounting the wonders there revealed. As in other cases, however, the realities of science have proved more varied and surprising than the dreams of fiction. Of the gigantic and extraordinary animals thus revealed to us by far the greatest number have been described during the period now under review. For instance, the gigantic Cetiosaurus was described by Owen in 1838, the Dinornis of New Zealand by the same distinguished naturalist in 1839, the Mylodon in the same year, and the Archæopteryx in 1862.

In America, a large number of remarkable forms have been described, mainly by Marsh, Leidy, and Cope. Marsh has made known to us the Titanosaurus, of the American (Colorado) Jurassic beds, which is, perhaps, the largest land animal yet known, being a hundred feet in length, and at least thirty in height, though it seems possible that even these vast dimensions were exceeded by those of the Atlantosaurus. Nor must I omit the Hesperornis, described by Marsh in 1872, as a carnivorous, swimming ostrich, provided with teeth, which he regards as a character inherited from reptilian ancestors; the Ichthyornis, stranger still, with biconcave vertebræ, like those of fishes, and teeth set in sockets; while in the Eocene deposits of the Rocky Mountains the same indefatigable palæontologist, among other very interesting remains, has discovered three new groups of remarkable mammals, the Dinocerata, Tillodontia, and Brontotheridæ. He has also described a number of small, but very interesting Jurassic mammalia, closely related to those found in our Stonesfield Slate and Purbeck beds, for which he has proposed a new order, 'Prototheria.' Lastly, I may mention the curiously anomalous Reptilia from South Africa, which have been made known to us by Professor Owen.

Another important result of recent palæontological research is the law of brain-growth. It is not only in the higher mammalia that we find forms with brains much larger than any existing, say, in Miocene times. The rule is almost general that—as Marsh has briefly stated it—'all tertiary mammals had small brains.' We may even carry the generalisation further. The cretaceous birds had brains one-third smaller than those of our own day, and the brain-cavities of the Dinosauria of the Jurassic period are much smaller than in any existing reptiles.

As giving, in a few words, an idea of the rapid progress in this department, I may mention that Morris's 'Catalogue of British Fossils,' published in 1843, contained 5,300 species; while that now in preparation by Mr. Etheridge enumerates 15,000.

But if these figures show how rapid our recent progress has been, they also very forcibly illustrate the imperfection of the geological record, giving us, I will not say a measure, but an idea, of the imperfection of the geological record. The number of all the described recent species is over 300,000, but certainly not half are yet on our lists, and we may safely take the total number of recent species as being not less than 700,000. But in former times there have been at the very least twelve periods, in each of which by far the greater number of species were distinct. True, the number of species was probably not so large in the earlier periods as at present; but if we make a liberal allowance for this, we shall have a total of more than 2,000,000 species, of which about 25,000 only are as yet upon record; and many of these are only represented by a few, some only by a single specimen, or even only by a fragment.

The progress of palæontology may also be marked by the extent to which the existence of groups has been, if I may so say, carried back in time. Thus I believe that in 1830 the earliest known quadrupeds were small marsupials belonging to the Stonesfield slates; the most ancient mammal now known is Microlestes antiquus from the Keuper of Würtemberg: the oldest bird known in 1831 belonged to the period of the London Clay, the oldest now known is the Archæopteryx of the Solenhofen slates, though it is probable that some at any rate of the footsteps on the Triassic rocks are those of birds. So again the Amphibia have been carried back from the Trias to the Coal-measures; Fish from the Old Red Sandstone to the Upper Silurian; Reptiles to the Trias; Insects from the Cretaceous to the Devonian; Mollusca and Crustacea from the Silurian to the Lower Cambrian. The rocks below the Cambrian, though of immense thickness, have afforded no relics of animal life, if we except the problematical Eozoon Canadense, so ably studied by Dawson and Carpenter. But if palæontology as yet throws no light on the original forms of life, we must remember that the simplest and the lowest organisms are so soft and perishable that they would leave 'not a wrack behind.' I will not, however, enlarge on this branch of science, because we shall have the advantage on Friday of hearing it treated with the skill of a master.

Passing to the Science of Geography, Mr. Clements Markham has recently published an excellent summary of what has been accomplished during the half-century.

As regards the Arctic regions, in the year 1830 the coast line of Arctic America was only very partially known, the region between Barrow Strait and the continent, for instance, being quite unexplored, while the eastern sides of Greenland and Spitzbergen, and the coasts of Nova Zembla, were almost unknown. Now the whole coast of Arctic America has been delineated, the remarkable archipelago to the north has been explored, and no less than seven north-west passages—none of them, however, unfortunately of any practical value—have been traced. The north-eastern passage, on the other hand, so far at least as the mouths of the great Siberian rivers, may perhaps hereafter prove of commercial importance. In the Antarctic regions, Enderby and Graham Lands were discovered in 1831–2, Balleny Islands and Sabrina Land in 1839, while the fact of the existence of the great southern continent was established in 1841 by Sir James Ross, who penetrated in 1842 to 78° 11′, the southernmost point ever reached.

In Asia, to quote from Mr. Markham, 'our officers have mapped the whole of Persia and Afghanistan, surveyed Mesopotamia, and explored the Pamir steppe. Japan, Borneo, Siam, the Malay peninsula, and the greater part of China have been brought more completely to our knowledge. Eastern Turkestan has been visited, and trained native explorers have penetrated to the remotest fountains of the Oxus, and the wild plateaux of Tibet. Over the northern half of the Asiatic Continent the Russians have displayed great activity. They have traversed the wild steppes and deserts of what on old atlases was called Independent Tartary, have surveyed the courses of the Jaxartes, the Oxus, and the Amur, and have navigated the Caspian and the Sea of Aral. They have pushed their scientific investigations into the Pamir and Eastern Turkestan, until at last the British and Russian surveys have been connected.'

Again, fifty years ago the vast central regions of Africa were almost a blank upon our best maps. The rudely drawn lakes and rivers in maps of a more ancient date had become discredited. They did not agree among themselves, the evidence upon which they were laid down could not be found, they were in many respects highly improbable, and they seemed inconsistent with what had then been ascertained concerning the Niger and the Blue and White Niles. At the date of which I speak, the Sahara had been crossed by English travellers from the shores of the Mediterranean; but the southern desert still formed a bar to travellers from the Cape, while the accounts of traders and others who alone had entered the country from the eastern and western coasts were considered to form an insufficient basis for a map.

Since that time the successful crossing of the Kalahari desert to Lake Ngami has been the prelude to an era of African discovery. Livingstone explored the basin of the Zambesi, and discovered vast lakes and waters which have proved to be those of the higher Congo. Burton and Speke opened the way from the West Coast, which Speke and Grant pursued into and down the Nile, and Stanley down the course of the middle and lower Congo; and the vast extension of Egyptian dominion has brought a huge slice of equatorial Africa within the limits of semi-civilisation. The western side of Africa has been attacked at many points. Alexander and Galton were among the first to make known to us its western tropical regions immediately to the north of the Cape Colony; the Ogowé has been explored; the Congo promises to become a centre of trade, and the navigable portions of the Niger, the Gambia, and the Senegal are familiarly known.

The progress of discovery in Australia has been as remarkable as that in Africa. The interior of this great continent was absolutely unknown to us fifty years ago, but is now crossed through its centre by the electric telegraph, and no inconsiderable portion of it is turned into sheep-farms. It is an interesting fact that General Sabine, so long one of our most active officers, and who is still with us, though, unfortunately, his health has for some time prevented him from attending our meetings, was born on the very day that the first settler landed in Australia.

In hydrography our charts have been immensely improved. The study of rivers and of the physical geography of the sea may indeed almost be said to have come into existence as a science during the last fifty years, and in the words of Jansen, it was Maury 'who, by his wind and current charts, his trade-wind, storm, and rain charts, and last, but not least, by his work on the physical geography of the sea, gave the first great impulse to all subsequent researches.'

But the progress in our knowledge of geography is, and has been, by no means confined to the improvement of our maps, or to the discovery and description of new regions of the earth; but has extended to the causes which have led to the present configuration of the surface. To a great extent indeed this part of the subject falls rather within the scope of geology, but I may here refer, in illustration, to the distribution of lakes, the phenomena of glaciers, the formation of volcanic mountains, and the structure and distribution of coral islands.

The origin and distribution of lakes is one of the most interesting problems in physical geography. That they are not scattered at random, a glance at the map is sufficient to show. They abound in mountain districts, are comparatively rare in equatorial regions, increasing in number as we go north, so that in Scotland and the northern parts of America they are sown broadcast.

Perhaps *à priori* the first explanation of the origin of lakes which would suggest itself, would be that they were formed in hollows resulting from a disturbance of the strata, which had thrown them into a basin-shaped form. Lake-basins, however, of this character are, as a matter of fact, very rare; as a general rule lakes have not the form of basin-shaped synclinal hollows, but, on the contrary, the strike of the strata often runs right across them. My eminent predecessor, Professor Ramsay, divides lakes into three classes:—(1) Those which are due to irregular accumulations of drift, and which are generally quite shallow. (2) Those which are formed by moraines, and (3) those which occupy true basins scooped by glacier-ice out of the solid rock. To the latter class belong, in his opinion, most of the great Swiss and Italian lakes. Professor Ramsay attributes their excavation to glaciers, because it is of course obvious that rivers cannot make basin-shaped hollows surrounded by rock on all sides. Now the Lake of Geneva, 1,230 feet above the sea, is 984 feet deep, the Lake of Brienz is 1,850 feet above the sea, and 2,000 feet deep, so that its bottom is really below the sea-level. The Italian lakes are even more remarkable. The Lake of Como, 700 feet above the sea, is 1,929 feet deep. Lago Maggiore, 685 feet above the sea, is no less than 2,625 feet deep. It will be observed that these lakes, like many others in mountain regions—those of Scandinavia, for instance—lie in the direct channels of the great old glaciers. If the mind is at first staggered at the magnitude of the scale, we must remember that the ice which scooped out the valley in which the Lake of Geneva now reposes, was once at least 2,700 feet thick; while the moraines were also of gigantic magnitude, that of Ivrea, for instance, being no less than 1,500 feet in height. Professor Ramsay's theory seems, therefore, to account beautifully for a large number of interesting facts.

The problem is, however, very complex; and, while admitting the force of Professor Ramsay's arguments, there are, no doubt, other causes which have exercised a considerable influence in the arrangement and configuration of lakes; for instance—as has been ably argued by our new secretary, Professor Bonney—irregular movements of upheaval along lines athwart the valleys.

Passing from lakes to mountains, two rival theories with reference to the structure and origin of volcanoes long struggled for supremacy.

The more general view was that the sheets of lava and scoriæ which form volcanic cones—such, for instance, as Ætna or Vesuvius—were originally nearly horizontal, and that subsequently a force operating from below, and exerting a pressure both upwards and outwards from a central axis towards all points of the compass, uplifted the whole stratified mass and made it assume a conical form, giving rise at the same time, in many cases, to a wide and deep circular opening at the top of the cone, called by the advocates of this hypothesis a 'crater of elevation.'

This theory, though, as it seems to us now, it had already received its death-blow from the admirable memoirs of Scrope, was yet that most generally adopted fifty years ago, because it was considered that compact and crystalline lavas could not have consolidated on a slope exceeding 1° or 2°. In 1858, however, Sir C. Lyell conclusively showed that in fact such lavas could consolidate at a considerable angle, even in some cases at more than 30°, and it is now generally admitted that though the beds of lava, &c., may have sustained a slight angular elevation since their deposition, still in the main, volcanic cones have acquired their form by the accumulation of lava and ashes ejected from one or more craters.

The problems presented by glaciers are of very great interest. In 1843 Agassiz and Forbes proved that the centre of a glacier, like that of a river, moves more rapidly than its sides. But how and why do glaciers move at all? Rendu, afterwards Bishop of Anneçy, in 1841 endeavoured to explain the facts by supposing that glacier ice enjoys a kind of ductility. The 'viscous theory' of glaciers was also adopted, and most ably advocated, by Forbes, who compared the condition of a glacier to that of the contents of a tar barrel poured into a sloping channel. We have all, however, seen long narrow fissures, a mere fraction of an inch in width, stretching far across glaciers—a condition incompatible with the ordinary idea of viscosity. The phenomenon of regelation was afterwards applied to the explanation of glacier-motion. An observation of Faraday's supplied the clue. He noticed in 1850 that when two pieces of thawing ice are placed together they unite by freezing at the place of contact. Following up this suggestion Tyndall found that if he compressed a block of ice in a mould it could be made to assume any shape he pleased. A straight prism, for instance, placed in a groove and submitted to hydraulic pressure, was bent into a transparent semicircle of ice. These experiments seem to have proved that a glacial valley is a mould through which the ice is forced, and to which it will accommodate itself, while, as Tyndall and Huxley also pointed out, the 'veined structure of ice' is produced by pressure, in the same manner as the cleavage of slate rocks.

It was in the year 1842 that Darwin published his great work on 'Coral Islands.' The fringing reefs of coral presented no special difficulty. They could be obviously accounted for by an elevation of the land, so that the coral which had originally grown under water, had been raised above the sea-level. The circular or oval shape of so many reefs, however, each having a lagoon in the centre, closely surrounded by a deep ocean, and rising but a few feet above the sea-level, had long been a puzzle to the physical geographer. The favourite theory was that these were the summits of submarine volcanoes on which the coral had grown. But as the reef-making coral does not live at greater depths than about twenty-five fathoms, the immense number of these reefs formed an almost insuperable objection to this theory. The Laccadives and Maldives, for instance—meaning literally the 'lac of islands' and the 'thousand islands'—are a series of such atolls, and it was impossible to imagine so great a number of craters, all so nearly of the same altitude. Darwin showed, moreover, that so far from the ring of corals resting on a corresponding ridge of rock, the lagoons, on the contrary, now occupy the place which was once the highest land. He pointed out that some lagoons, as for instance, that of Vanikoro, contain an island in the middle; while other islands, such as Tahiti, are surrounded by a margin of smooth water, separated from the ocean by a coral reef. Now, if we suppose that Tahiti were to sink slowly, it would gradually approximate to the condition of Vanikoro; and if Vanikoro gradually sank, the central island would disappear, while on the contrary the growth of the coral might neutralise the subsidence of the reef, so that we should have simply an atoll, with its lagoon. The same considerations explain the origin of the 'barrier reefs,' such as that which runs, for nearly one thousand miles, along the north-east coast of Australia. Thus Darwin's theory explained the form and the approximate identity of altitude of these coral islands. But it did more than this, because it showed us that there were great areas in process of subsidence, which, though slow, was of great importance in physical geography.[1]

Much information has also been acquired with reference to the abysses of the ocean, especially from the voyages of the *Porcupine* and the *Challenger*. The greatest depth yet recorded is near the Ladrone Islands, where a sounding of 4,575 fathoms was obtained.

Ehrenberg long ago pointed out the similarity of the calcareous mud now accumulating in our recent seas to the chalk, and showed that the green sands of the geologist are largely made up of casts of foraminifera. Clay, however, had been looked on, until the recent expeditions, as essentially a product of the disintegration of older rocks. Not only, however, are a large proportion of siliceous and calcareous rocks either directly or indirectly derived from material which has once formed a portion of living organisms, but Sir Wyville Thomson maintains that

[1] I ought to mention that Darwin's views have recently been questioned by Semper and Murray.

this is the case with some clays also. In that case the striking remark of Linnæus, that 'fossils are not the children but the parents of rocks,' will have received remarkable confirmation. I should have thought it, I confess, probable that these clays are, to a considerable extent, composed of volcanic dust.

It would appear that calcareous deposits resembling our chalk do not occur at a greater depth than 3,000 fathoms; they have not been met with in the abysses of the ocean. Here the bottom consists of exceedingly fine clay, sometimes coloured red by oxide of iron, sometimes chocolate by manganese oxide, and containing with Foraminifera occasionally large numbers of siliceous Radiolaria. These strata seem to accumulate with extreme slowness: this is inferred from the comparative abundance of whales' bones and fishes' teeth; and from the presence of minute spherical particles, supposed by Mr. Murray to be of cosmic origin—in fact, to be the dust of meteorites, which in the course of ages have fallen on the ocean. Such particles no doubt occur over the whole surface of the earth, but on land they soon oxidise, and in shallow water they are covered up by other deposits. Another interesting result of recent deep-sea explorations has been to show that the depths of the ocean are no mere barren solitudes, as was until recent years confidently believed, but, on the contrary, present us many remarkable forms of life. We have, however, as yet but thrown here and there a ray of light down into the ocean abysses:—

> Nor can so short a time sufficient be
> To fathom the vast depths of Nature's sea.

In Astronomy, the discovery in 1845 of the planet Neptune, made independently and almost simultaneously by Adams and by Le Verrier, was certainly one of the very greatest triumphs of mathematical genius. Of the minor planets four only were known in 1831, whilst the number now on the roll amounts to 220. Many astronomers believe in the existence of an intra-mercurial planet or planets, but this is still an open question. The Solar System has also been enriched by the discovery of an inner ring to Saturn, of satellites to Mars, and of additional satellites to Saturn, Uranus, and Neptune.

The most unexpected progress, however, in our astronomical knowledge during the past half-century has been due to spectrum analysis.

The dark lines in the spectrum were first seen by Wollaston, who noticed a few of them; but they were independently discovered by Fraunhofer, after whom they are justly named, and who, in 1814, mapped no fewer than 576. The first steps in 'spectrum analysis,' properly so called, were made by Sir J. Herschel, Fox Talbot, and by Wheatstone, in a paper read before this Association in 1835. The latter showed that the spectrum emitted by the incandescent vapour of metals was formed of bright lines, and that these lines, while, as he then supposed, constant for each metal, differed for different metals. 'We have here,' he said, 'a mode of discriminating metallic bodies more readily than that of chemical examination, and which may hereafter be employed for useful purposes.' Nay, not only can bodies thus be more readily discriminated, but, as we now know, the presence of extremely minute portions can be detected, the $\frac{1}{5000000}$ of a grain being in some cases easily perceptible.

It is also easy to see that the presence of any new simple substance might be detected, and in this manner already several new elements have been discovered, as I shall mention when we come to Chemistry.

But spectrum analysis has led to even grander and more unexpected triumphs. Fraunhofer himself noticed the coincidence between the double dark line D of the solar spectrum and a double line which he observed in the spectra of ordinary flames, while Stokes pointed out to Sir W. Thomson, who taught it in his lectures, that in both cases these lines were due to the presence of sodium. To Kirchhoff and Bunsen, however, is due the independent conception and the credit of having first systematically investigated the relation which exists between Fraunhofer's lines and the bright lines in the spectra of incandescent metals. In order to get some fixed measure by which they might determine and record the lines characterising any given substance, it occurred to them that they might use for comparison the spectrum of the sun. They accordingly arranged their spectroscope so that one-half of the slit was lighted by the sun, and the other by the luminous gases they proposed to examine. It immediately struck them that the bright lines in the one corresponded with the dark lines in the other—the bright line of sodium, for instance, with the line or rather lines D in the sun's spectrum. The conclusion was obvious. There was sodium in the sun. It must indeed have been a glorious moment when that thought flashed across them, and even by itself well worth all their labour.

But why is the bright line of a sodium flame represented by a black one in the spectrum of the sun? To Ångström is due the theory that a vapour or gas can absorb luminous rays of the same refrangibility only which it emits when highly heated; while Balfour Stewart independently discovered the same law with reference to radiant heat.

This is the basis of Kirchhoff's theory of the origin of Fraunhofer's lines. In the atmosphere of the sun the vapours of various metals are present, each of which would give its characteristic lines, but within this atmospheric envelope is the still more intensely heated nucleus of the sun, which emits a brilliant continuous spectrum, containing rays of all degrees of refrangibility. When the light of this intensely heated nucleus is transmitted through the surrounding atmosphere, the bright lines which would be produced by this atmosphere are seen as dark ones.

Kirchhoff and Bunsen thus proved the existence in the sun of hydrogen, sodium, magnesium, calcium, iron, nickel, chromium, manganese, titanium, and cobalt; since which Ångström, Thalen, and Lockyer have considerably increased the list.

But it is not merely the chemistry of the heavenly bodies on which light is thrown by the spectroscope; their physical structure and evolutional history are also illuminated by this wonderful instrument of research.

It used to be supposed that the sun was a dark body enveloped in a luminous atmosphere. The reverse now appears to be the truth. The body of the sun, or photosphere, is intensely brilliant; round it lies the solar atmosphere of comparatively cool gases, which cause the dark lines in the spectrum; thirdly, a chromosphere,—a sphere principally of hydrogen, jets of which are said sometimes to reach to a height of 100,000 miles or more, into the outer coating or corona, the nature of which is still very doubtful.

Formerly the red flames which represent the higher regions of the chromosphere could be seen only on the rare occasions of a total solar eclipse. Janssen and Lockyer, by the application of the spectroscope, have enabled us to study this region of the sun at all times.

It is, moreover, obvious that the powerful engine of investigation afforded us by the spectroscope is by no means confined to the substances which form part of our system. The incandescent body can thus be examined, no matter how great its distance, so long only as the light is strong enough. That this method was theoretically applicable to the light of the stars was indeed obvious, but the practical difficulties were very great. Sirius, the brightest of all, is, in round numbers, a hundred millions of millions of miles from us; and, though as big as sixty of our suns, his light when it reaches us, after a journey of sixteen years, is at most one two-thousand-millionth part as bright. Nevertheless as long ago as 1815 Fraunhofer recognised the fixed lines in the light of four of the stars, and in 1863 Miller and Huggins in our own country, and Rutherford in America, succeeded in determining the dark lines in the spectrum of some of the brighter stars, thus showing that these beautiful and mysterious lights contain many of the material substances with which we are familiar. In Aldebaran, for instance, we may infer the presence of hydrogen, sodium, magnesium, iron, calcium, tellurium, antimony, bismuth, and mercury; some of which are not yet known to occur in the sun. As might have been expected the composition of the stars is not uniform, and it would appear that they may be arranged in a few well-marked classes, indicating differences of temperature or, in other words, of age. Some recent photographic spectra of stars obtained by Huggins go very far to justify this view.

Thus we can make the stars teach us their own composition with light which started from its source before we were born—light older than our Association itself.

Until 1864, the true nature of the unresolved nebulæ was a matter of doubt. In that year, however, Huggins turned his spectroscope on to a nebula, and made the unexpected discovery that the spectra of some of these bodies are discontinuous—that is to say, consist of bright lines only, indicating that 'in place of an incandescent solid or liquid body we must probably regard these objects, or at least their photo-surfaces, as enormous masses of luminous gas or vapour. For it is from matter in a gaseous state only that such light as that of the nebulæ is known to be emitted.' So far as observation has yet gone, nebulæ may be divided into two classes: some giving a continuous spectrum, others one consisting of bright lines. These latter all appear to give essentially the same spectrum, consisting of a few bright lines. Two of them, in Mr. Huggins' opinion, indicate the presence of hydrogen: one of them agrees in position with a line characteristic of nitrogen.

But spectrum analysis has even more than this to tell us. The old methods of observation could determine the movements of the stars so far only as they were transverse to us; they afforded no means of measuring motion either directly towards or away from us. Now Döppler suggested in 1841 that the colors of the stars would assist us in this respect, because they would be affected by their motion to and from the earth, just as a steam-whistle is raised or lowered as it approaches or recedes from us. Everyone has observed that if a train whistles as it passes us, the sound appears to alter at the moment the engine goes by. This arises, of course, not from any change in the whistle itself, but because the number of vibrations which reach the ear in a given time are increased by the speed of the train as it approaches, and diminished as it recedes. So, like the sound, the color would be affected by such a movement; but Döppler's method was practically inapplicable, not only because the amount of effect on the color would be hardly sensible, but also for other reasons; indeed, as we did not know the true color of the stars, we had no datum line by which to measure.

A change of refrangibility of light, however, does occur in consequence of relative motion, and Huggins successfully applied the spectroscope to solve the problem. He took in the first place the spectroscope of Sirius, and chose a line known as F, which is due to hydrogen. Now, if Sirius was motionless, or rather if it retained a constant distance from the earth, the line F would occupy exactly the same position in the spectrum of Sirius as in that of the sun. On the contrary, if Sirius were approaching or receding from us, this line would be slightly shifted either towards the blue or red end of the spectrum. He found that the line had moved very slightly towards the red, indicating that the distance between us and Sirius is increasing at the rate of about twenty miles a second. So also Betelgeux, Rigel, Castor, and Regulus are increasing their distance; while, on the contrary, that of others, as for instance of Vega, Arcturus, and Pollux, is diminishing. The results obtained by Huggins on about twenty stars have since been confirmed and extended by Mr. Christie, now Astronomer Royal, in succession to Sir G. Airy, who has long occupied the post with so much honour to himself and advantage to science.

To examine the spectrum of a shooting star would seem even more difficult. Alexander Herschel first succeeded in doing so, and determined the presence of sodium; since which Von Konkoly has recognised the lines of magnesium, carbon, potassium, lithium and other substances, and it appears that the shooting stars are bodies similar in character and composition to the stony masses which sometimes reach the earth as aërolites.

Some light has also been thrown upon those mysterious visitants, the comets. The researches of Prof. Newton on the periods of meteoroids led to the remarkable discovery by Schiaparelli of the identity of the orbits of some meteor-swarms with those of some comets. The similarity of orbits is too striking to be the result of chance, and shows a true cosmical relation between the bodies. Comets, in fact, are in some cases at any rate groups of meteoric stones. From the spectra of the small comets of 1866 and 1868, Huggins showed that part of their light is emitted by themselves, and reveals the presence of carbon in some form. A photographic spectrum of the comet recently visible, obtained by the same observer, is considered by him to prove that nitrogen, probably in combination with carbon, is also present.

No element has yet been found in any meteorite, which was not previously known as existing in the earth, but the phenomena which they exhibit indicate that they must have been formed under conditions very different from those which prevail on the earth's surface. I may mention, for instance, the peculiar form of crystallised silica, called by Maskelyne, Asmanite; and the whole class of meteorites, consisting of iron generally alloyed with nickel, which Daubrée terms Holosiderites. The interesting discovery, however, by Nordenskiöld, in 1870, at Ovifak, of a number of blocks of iron alloyed with nickel and cobalt, in connection with basalts containing disseminated iron, has, in the words of Judd, 'afforded a very important link, placing the terrestrial and extra-terrestrial rocks in closer relations with one another.'

We have as yet no sufficient evidence to justify a conclusion as to whether any substances exist in the heavenly bodies which do not occur in our earth, though there are many lines which cannot yet be satisfactorily referred to any terrestrial element. On the other hand, some substances which occur on our earth have not yet been detected in the sun's atmosphere.

Such discoveries as these seemed, not long ago, entirely beyond our hopes. M. Comte, indeed, in his 'Cours de Philosophie Positive,' as recently as 1842, laid it down as an axiom regarding the heavenly bodies, that 'Nous concevons la possibilité de déterminer leurs formes, leurs distances, leurs grandeurs et leurs mouvements, tandis que nous ne saurions jamais étudier par aucun moyen leur composition chimique ou leur structure minéralogique.' Yet within a few years this supposed impossibility has been actually accomplished, showing how unsafe it is to limit the possibilities of science.

It is hardly necessary to point out that, while the spectrum has taught us so much, we have still even more to learn. Why should some substances give few, and others many, lines? Why should the same substance give different lines at different temperatures? What are the relations between the lines and the physical or chemical properties?

We may certainly look for much new knowledge of the hidden actions of atoms and molecules from future researches with the spectroscope. It may even, perhaps, teach us to modify our views of the so-called simple substances. Prout, long ago, struck by the remarkable fact that nearly all atomic weights are simple multiples of the atomic weight of hydrogen, suggested that hydrogen must be the primordial substance. Brodie's researches also naturally fell in with the supposition that the so-called simple substances are in reality complex, and that their constituents occur separately in the hottest regions of the solar atmosphere. Lockyer considers that his researches lend great probability to this view. The whole subject is one of intense interest, and we may rejoice that it is occupying the attention, not only of such men as Abney, Dewar, Hartley, Liveing, Roscoe and Schuster in our own country, but also of many foreign observers.

When geology so greatly extended our ideas of past time, the continued heat of the sun became a question of greater interest than ever. Helmholtz has shown that, while adopting the nebular hypothesis, we need not assume that the nebulous matter was originally incandescent; but that its present high temperature may be, and probably is, mainly due to gravitation between its parts. It follows that the potential energy of the sun is far from exhausted, and that with continued shrinking it will continue to give out light and heat, with little, if any, diminution for several millions of years.

Like the sand of the sea, the stars of heaven have ever been used as effective symbols of number, and the improvements in our methods of observation have added fresh force to our original impressions. We now know that our earth is but a fraction of one out of at least 75,000,000 worlds.

But this is not all. In addition to the luminous heavenly bodies, we cannot doubt that there are countless others, invisible to us from their greater distance, smaller size, or feebler light; indeed we know that there are many dark bodies which now emit no light or comparatively little. Thus in the case of Procyon, the existence of an invisible body is proved by the movement of the visible star. Again I may refer to the curious phenomena presented by Algol, a bright star in the head of Medusa. This star shines without change for two days and thirteen hours; then, in three hours and a half, dwindles from a star of the second to one of the fourth magnitude; and then, in another three and a half hours, reassumes its original brilliancy. These changes seem certainly to indicate the presence of an opaque body, which intercepts at regular intervals a part of the light emitted by Algol.

Thus the floor of heaven is not only 'thick inlaid with patines of bright gold,' but studded also with extinct stars; once probably as brilliant as our own sun, but now dead and cold, as Helmholtz tells us that our sun itself will be, some seventeen millions of years hence.

The connection of Astronomy with the history of our planet has been a subject of speculation and research during a great part of the half-century of our existence. Sir Charles Lyell devoted some of the opening chapters of his great work to the subject. Haughton has brought his very original powers to bear on the subject of secular changes in climate, and Croll's contributions to the same subject are of great interest. Last, but not least, I must not omit to make mention of the series of massive memoirs (I am happy to say not yet nearly terminated) by George Darwin on tidal friction, and the influence of tidal action on the evolution of the solar system.

I may perhaps just mention, as regards telescopes, that the largest reflector in 1830 was Sir W. Herschel's of 4 ft., the largest at present being Lord Rosse's of 6 ft.; as regards refractors the largest then had a diameter of $11\frac{1}{4}$ in., while your fellow-townsman Cooke carried the size to 25 in., and Mr. Grubb, of Dublin, has just successfully completed one of 27 in. for the Observatory of Vienna. It is remarkable that the two largest telescopes in the world should both be Irish.

The general result of astronomical researches has been thus eloquently summed up by Proctor:—'The sidereal system is altogether more complicated and more varied in structure than has hitherto been supposed; in the same region of the stellar depths co-exist stars of many orders of real magnitude; all orders of nebulæ, gaseous or stellar, planetary, ring-formed, elliptical, and spiral, exist within the limits of the galaxy; and lastly, the whole system is alive with movements, the laws of which may one day be recognised, though at present they appear too complex to be understood.'

We can, I think, scarcely claim the establishment of the undulatory theory of light as falling within the last fifty years; for though Brewster, in his 'Report on Optics,' published in our first volume, treats the question as open, and expresses himself still unconvinced, he was, I believe, almost alone in his preference for the emission theory. The phenomena of interference, in fact, left hardly any—if any—room for doubt, and the subject was finally set at rest by Foucault's celebrated experiments in 1850. According to the undulatory theory the velocity of light ought to be greater in air than in water, while if the emission theory were correct the reverse would be the case. The velocity of light—186,000 miles in a second—is, however, so great that, to determine its rate in air, as compared with that in water, might seem almost hopeless. The velocity in air was, nevertheless, determined by Fizeau in 1849, by means of a rapidly revolving wheel. In the following year Foucault, by means of a revolving mirror, demonstrated that the velocity of light is greater in air than in water—thus completing the evidence in favour of the undulatory theory of light.

The idea is now gaining ground, that, as maintained by Clerk-Maxwell, light itself is an electro-magnetic disturbance, the luminiferous ether being the vehicle of both light and electricity.

Wünsch, as long ago as 1792, had clearly shown that the three primary colors were red, green, and violet; but his results attracted little notice, and the general view used to be that there were seven principal colors—red, orange, yellow, green, blue, indigo, and violet; four of which—namely orange, green, indigo, and violet—were considered to arise from mixtures of the other three. Red, yellow, and blue were therefore called the primary colors, and it was supposed that in order to produce white light these three colors must always be present.

Helmholtz, however, again showed, in 1852, that a color to our unaided eyes identical with white, was produced by combining yellow with indigo. At that time yellow was considered to be a simple color, and this, therefore, was regarded as an exception to the general rule, that a combination of three simple colors is required to produce white. Again, it was, and indeed still is, the general impression that a combination of blue and yellow makes green. This, however, is entirely a mistake. Of course we all know that yellow paint and blue paint make green paint; but this results from absorption of light by the semi-transparent solid particles of the pigments, and is not a mere mixture of the colors proceeding unaltered from the yellow and the blue particles: moreover, as can easily be shown by two sheets of colored paper and a piece of window glass, blue and yellow light, when combined, do not give a trace of green, but if pure would produce the effect of white. Green, therefore, is after all not produced by a mixture of blue and yellow. On the other hand, Clerk-Maxwell proved in 1860 that yellow could be produced by a mixture of red and green, which put an end to the pretension of yellow to be considered a primary element of color. From these and other considerations it would seem, therefore, that the three primary colors—if such an expression be retained—are red, green, and violet.

The existence of rays beyond the violet, though almost invisible to our eyes, had long been demonstrated by their chemical action. Stokes, however, showed in 1852 that their existence might be proved in another manner, for that there are certain substances which, when excited by them, emit light visible to our eyes. To this phenomenon he gave the name of fluorescence. At the other end of the spectrum Abney has recently succeeded in photographing a large number of lines in the infra-red portion, the existence of which was first proved by Sir William Herschel.

From the rarity, and in many cases the entire absence, of reference to blue, in ancient literature, Geiger—adopting and extending a suggestion first thrown out by Mr. Gladstone—has maintained that, even as recently as the time of Homer, our ancestors were blue-blind. Though for my part I am unable to adopt this view, it is certainly very remarkable that neither the Rigveda, which consists almost entirely of hymns to heaven, nor the Zendavesta, the Bible of the Parsees or fire-worshippers, nor the earlier books of the Old Testament, nor the Homeric poems, ever allude to the sky as blue.

On the other hand, from the dawn of poetry, the splendours of the morning and evening skies have excited the admiration of mankind. As Ruskin says, in language almost as brilliant as the sky itself, the whole heaven, 'from the zenith to the horizon, becomes one molten, mantling sea of colour and fire; every black bar turns into massy gold, every ripple and wave into unsullied shadowless crimson, and purple, and scarlet, and colours for which there are no words in language, and no ideas in the mind—things which can only be conceived while they are visible; the intense hollow blue of the upper sky melting through it all, showing here deep, and pure, and lightness; there, modulated by the filmy, formless body of the transparent vapour, till it is lost imperceptibly in its crimson and gold.'

But what is the explanation of these gorgeous colors? why is the sky blue? and why are the sunrise and sunset crimson and gold? It may be said that the air is blue, but if so how can the clouds assume their varied tints? Brücke showed that very minute particles suspended in water are blue by reflected light. Tyndall has taught us that the blue of the sky is due to the reflection of the blue rays by the minute particles floating in the atmosphere. Now if from the white light of the sun the blue rays are thus selected, those which are transmitted will be yellow, orange, and red. Where the distance is short the transmitted light will appear yellowish. But as the sun sinks towards the horizon the atmospheric distance increases, and consequently the number of the scattering particles. They weaken in succession the violet, the indigo, the blue, and even disturb the proportions of green. The transmitted light under such circumstances must pass from yellow through orange to red, and thus, while we at noon are admiring the deep blue of the sky, the same rays, robbed of their blue, are elsewhere lighting up the evening sky with all the glories of sunset.

Another remarkable triumph of the last half-century has been the discovery of photography. At the commencement of the century Wedgwood and Davy observed the effect produced by throwing the images of objects on paper or leather prepared with nitrate of silver, but no means were known by which such images could be fixed. This was first effected by Niepce, but his processes were open to objections, which prevented them from coming into general use, and it was not till 1839 that Daguerre invented the process which was justly named after him. Very soon a further improvement was effected by our countryman Talbot. He not only fixed his 'Talbotypes' on paper—in itself a great convenience—but, by obtaining a negative, rendered it possible to take off any number of positive, or natural, copies from one original picture. This process is the foundation of all the methods now in use; perhaps the greatest improvements having been the use of glass plates, first proposed by Sir John Herschel; of collodion, suggested by Le Grey, and practically used by Archer; and, more lately, of gelatine, the foundation of the sensitive film now growing into general use in the ordinary dry-plate process. Not only have a great variety of other beautiful processes been invented, but the delicacy of the sensitive film has been immensely increased, with the advantage, among others, of diminishing greatly the time necessary for obtaining a picture, so that even an express train going at full speed can now be taken. Indeed, with full sunlight $\frac{1}{600}$ of a second is enough, and in photographing the sun itself $\frac{1}{60000}$ of a second is sufficient.

We owe to Wheatstone the conception that the idea of solidity is derived from the combination of two pictures of the same object in slightly different perspective. This he proved in 1833 by drawing two outlines of some geometrical figure or other simple object, as they would appear to either eye respectively, and then placing them so that they might be seen, one by each eye. The 'stereoscope,' thus produced, has been greatly popularised by photography.

For 2,000 years the art of lighting had made little if any progress. Until the close of the last century, for instance, our lighthouses contained mere fires of wood or coal, though the construction had vastly improved. The Eddystone lighthouse, for instance, was built by Smeaton in 1759; but for forty years its light consisted of a row of tallow candles stuck in a hoop. The Argand lamp was the first great improvement, followed by gas, and in 1863 by the electric light.

Just as light was long supposed to be due to the emission of material particles, so heat was regarded as a material, though ethereal, substance, which was added to bodies when their temperature was raised.

Davy's celebrated experiment of melting two pieces of ice by rubbing them against one another in the exhausted receiver of an air-pump had convinced him that the cause of heat was the motion of the invisible particles of bodies, as had been long before suggested by Newton, Boyle, and Hooke. Rumford and Young also advocated the same view. Nevertheless, the general opinion, even until the middle of the present century, was that heat was due to the presence of a subtle fluid known as 'caloric,' a theory which is now entirely abandoned.

Melloni, by the use of the electric pile, vastly increased our knowledge of the phenomena of radiant heat. His researches were confined to the solid and liquid forms of matter. Tyndall studied the gases in this respect, showing that differences greater than those established by Melloni existed between gases and vapours, both as regards the absorption and radiation of heat. He proved, moreover, that the aqueous vapour of our atmosphere, by checking terrestrial radiation, augments the earth's temperature, and he considers that the existence of tropical vegetation—the remains of which now constitute our coal-beds—may have been due to the heat retained by the vapours which at that period were diffused in the earth's atmosphere. Indeed, but for the vapour in our atmosphere, a single night would suffice to destroy the whole vegetation of the temperate regions.

Inspired by a contemplation of Graham Bell's ingenious experiments with intermittent beams on solid bodies, Tyndall took a new and original departure; and regarding the sounds as due to changes of temperature he concluded that the same method would prove applicable to gases. He thus found himself in possession of a new and independent method of procedure. It need perhaps be hardly added that, when submitted to this new test, his former conclusions on the interaction of heat and gaseous matter stood their ground.

The determination of the mechanical equivalent of heat is mainly due to the researches of Mayer and Joule. Mayer, in 1842, pointed out the mechanical equivalent of heat as a fundamental datum to be determined by experiment. Taking the heat produced by the condensation of air as the equivalent of the work done in compressing the air, he obtained a numerical value of the mechanical equivalent of heat. There was, however, in these experiments, one weak point. The matter operated on did not go through a cycle of changes. He assumed that the production of heat was the only effect of the work done in compressing the air. Joule had the merit of being the first to meet this possible source of error. He ascertained that a weight of 1 lb. would have to fall 772 feet in order to raise the temperature of 1 lb. of water by 1° Fahr. Hirn subsequently attacked the problem from the other side, and showed that if all the heat passing through a steam-engine were turned into work, for every degree Fahr. added to the temperature of a pound of water, enough work could be done to raise a weight of 1 lb. to a height of 772 feet. The general result is that, though we cannot create energy we may help ourselves to any extent from the great storehouse of nature. Wind and water, the coal-bed and the forest, afford man an inexhaustible supply of available energy.

It used to be considered that there was an absolute break between the different states of matter. The continuity of the gaseous, liquid, and solid conditions was first demonstrated by Andrews in 1862.

Oxygen and nitrogen have been liquefied independently and at the same time by Cailletet and Raoul Pictet. Cailletet also succeeded in liquefying air, and soon afterwards hydrogen was liquefied by Pictet under a pressure of 650 atmospheres, and a cold of 170° Cent. below zero. It even became partly solidified, and he assures us that it fell on the floor with 'the shrill noise of metallic hail.' Thus then it was shown experimentally that there are no such things as absolutely permanent gases.

The kinetic theory of gases, now generally accepted, refers the elasticity of gases to a motion of translation of their molecules, and we are assured that in the case of hydrogen at a temperature of 60° Fahr. they move at an average rate of 6,225 feet in a second; while, as regards their size, Loschmidt, who has since been confirmed by Stoney and Sir W. Thomson, calculates that each is at most $\frac{1}{500000000}$ of an inch in diameter.

We cannot, it would seem at present, hope for any increase of our knowledge of atoms by any improvement in the microscope. With our present instruments we can perceive lines ruled on glass $\frac{1}{90000}$th of an inch apart. But, owing to the properties of light itself, the fringes due to interference begin to produce confusion at distances of $\frac{1}{74000}$, and in the brightest part of the spectrum at little more than $\frac{1}{90000}$th they would make the obscurity more or less complete. If indeed we could use the blue rays by themselves, their waves being much shorter, the limit of possible visibility might be extended to $\frac{1}{120000}$; and as Helmholtz has suggested, this perhaps accounts for Stinde having actually been able to obtain a photographic image of lines only $\frac{1}{100000}$th of an inch apart. It would seem then that, owing to the physical characters of light, we can, as Sorby has pointed out, scarcely hope for any great improvement so far as the mere visibility of structure is concerned, though in other respects no doubt much may be hoped for. At the same time, Dallinger and Royston Pigott have shown that, so far as the mere presence of simple objects is concerned, bodies of even smaller dimensions can be perceived.

According to the views of Helmholtz, the size of the smallest particle that could be distinctly defined, when associated with others, is about $\frac{1}{80000}$th of an inch. Sorby estimates that a particle of albumen of this size contains 125 millions of molecules. In the case of such a simple compound as water the number is 8,000 millions. Even, then, if we could construct microscopes far more powerful than any we now possess, they would not enable us to obtain by direct vision any idea of the ultimate molecules of matter. Sorby calculates that the smallest sphere of organic matter which could be clearly defined with our most powerful microscopes would contain many millions of molecules of albumen and water, and it follows that there may be an almost infinite number of structural characters in organic tissues, which we can at present foresee no mode of examining.

The Science of Meteorology has made great progress; the weather, which was formerly treated as a local phenomenon, being now shown to form part of a vast system of mutually dependent cyclonic and anticyclonic movements. The storm-signals issued at our ports are very valuable to sailors, while the small weather-maps, for which we are mainly indebted to Francis Galton, and the forecasts, which anyone can obtain on application either personally or by telegraph at the Meteorological Office, are also of increasing utility.

Electricity in the year 1831 may be considered to have just been ripe for its adaptation to practical purposes; it was but a few years previously, in 1819, that Oersted had discovered the deflective action of the current on the magnetic needle, that Ampère had laid the foundation of electro-dynamics, that Schweizzer had devised the electric coil or multiplier, and that Sturgeon had constructed the first electro-magnet. It was in 1831 that Faraday, the prince of pure experimentalists, announced his discoveries of voltaic induction and magneto-electricity, which with the other three discoveries constitute the principles of nearly all the telegraph instruments now in use; and in 1834 our knowledge of the nature of the electric current had been much advanced by the interesting experiment of Sir Charles Wheatstone, proving the velocity of the current in a metallic conductor to approach that of the wave of light.

Practical applications of these discoveries were not long in coming to the fore, and the first telegraph line on the Great Western Railway from Paddington to West Drayton was set up in 1838. In America Morse is said to have commenced to develop his recording instrument between the years 1832 and 1837, while Steinheil, in Germany, during the same period was engaged upon his somewhat super-refined ink-recorder, using for the first time the earth for completing the return circuit; whereas in this country Cooke and Wheatstone, by adopting the more simple device of the double-needle instrument, were the first to make the electric telegraph a practical institution. Contemporaneously with, or immediately succeeding these pioneers, we find in this country Alexander Bain, Breguet in France, Schilling in Russia, and Werner Siemens in Germany, the last having first, in 1847, among others, made use of gutta-percha as an insulating medium for electric conductors, and thus cleared the way for subterranean and submarine telegraphy.

Four years later, in 1851, submarine telegraphy became an accomplished fact through the successful establishment of telegraphic communication between Dover and Calais. Submarine lines followed in rapid succession, crossing the English Channel and the German Ocean, threading their way through the Mediterranean, Black, and Red Seas, until in 1866, after two abortive attempts, telegraphic communication was successfully established between the Old and New Worlds, beneath the Atlantic Ocean.

In connection with this great enterprise and with many investigations and suggestions of a highly scientific and important character, the name of Sir William Thomson will ever be remembered. The ingenuity displayed in perfecting the means of transmitting intelligence through metallic conductors, with the utmost despatch and certainty as regards the record obtained, between two points hundreds and even thousands of miles apart is truly surprising. The instruments devised by Morse, Siemens, and Hughes have also proved most useful.

Duplex and quadruplex telegraphy, one of the most striking achievements of modern telegraphy, the result of the labours of several inventors, should not be passed over in silence. It not only serves for the simultaneous communication of telegraphic intelligence in both directions, but renders it possible for four instruments to be worked irrespectively of one another, through one and the same wire connecting two distant places.

Another more recent and perhaps still more wonderful achievement in modern telegraphy is the invention of the telephone and microphone, by means of which the human voice is transmitted through the electric conductor, by mechanism that imposes through its extreme simplicity. In this connection the names of Reiss, Graham Bell, Edison, and Hughes are those chiefly deserving to be recorded.

Whilst electricity has thus furnished us with the means of flashing our thoughts by record or by voice from place to place, its use is now gradually extending for the achievement of such quantitative effects as the production of light, the transmission of mechanical power, and the precipitation of metals. The principle involved in the magneto-electric and dynamo-electric machines, by which these effects are accomplished, may be traced to Faraday's discovery in 1831 of the induced current, but their realisation to the labours of Holmes, Siemens, Pacinotti, Gramme, and others. In the electric light, gas-lighting has found a formidable competitor, which appears destined to take its place in public illumination, and in lighting large halls, works, &c., for which purposes it combines brilliancy and freedom from obnoxious products of combustion, with comparative cheapness. The electric light seems also to threaten, when sub-divided in the manner recently devised by Edison, Swan, and others, to make inroads into our dwelling-houses.

By the electric transmission of power, we may hope some day to utilise at a distance such natural sources of energy as the Falls of Niagara, and to work our cranes, lifts, and machinery of every description by means of sources of power arranged at convenient centres. To these applications the brothers Siemens have more recently added the propulsion of trains by currents passing through the rails, the fusion in considerable quantities of highly refractory substances, and the use of electric centres of light in horticulture as proposed by Werner and William Siemens. By an essential improvement by Faure of the Planté Secondary Battery, the problem of storing electrical energy appears to have received a practical solution, the real importance of which is clearly proved by Sir William Thomson's recent investigation of the subject.

It would be difficult to assign the limits to which this development of electrical energy may not be rendered serviceable for the purposes of man.

As regards mathematics I have felt that it would be impossible for me, even with the kindest help, to write anything myself. Mr. Spottiswoode, however, has been so good as to supply me with the following memorandum.

In a complete survey of the progress of science during the half-century which has intervened between our first and our present meeting, the part played by mathematics would form no insignificant feature. To those indeed who are outside its enchanted circle it is difficult to realise the intense intellectual energy which actuates its devotees, or the wide expanse over which that energy ranges. Some measure, however, of its progress may perhaps be formed by considering, in one or two cases, from what simple principles some of the great recent developments have taken their origin.

Consider, for instance, what is known as the principle of signs. In geometry we are concerned with quantities such as lines and angles; and in the old systems a proposition was proved with reference to a particular figure. This figure might, it is true, be drawn in any manner within certain ranges of limitation; but if the limits were exceeded, a new proof, and often a new enunciation, became necessary. Gradually, however, it came to be perceived (*e.g.* by Carnot, in his 'Géometrie de Position,') that some propositions were true even when the quantities were reversed in direction. Hence followed a recognition of the principle (of signs) that every line should be regarded as a directed line, and every angle as measured in a definite direction. By means of this simple consideration, geometry has acquired a power similar to that of algebra, viz. of changing the signs of the quantities and transposing their positions, so as at once, and without fresh demonstration, to give rise to new propositions.

To take another instance. The properties of triangles, as established by Euclid, have always been considered as legitimate elements of proof; so that, when in any figure two triangles occur, their relations may be used as steps in a demonstration. But, within the period of which I am speaking, other general geometrical relations, *e.g.* those of a pencil of rays, or of their intersection with a straight line, have been recognised as serving a similar purpose. With what extensive results this generalisation has been attended, the Géometrie Supérieure of the late M. Chasles, and all the superstructure built on Anharmonic Ratio as a foundation, will be sufficient evidence.

Once more, the algebraical expression for a line or a plane involves two sets of quantities, the one relating to the position of any point in the line or plane, and the other relating to the position of the line or plane in space. The former set alone were originally considered variable, the latter constant. But as soon as it was seen that either set might at pleasure be regarded as variable, there was opened out to mathematicians the whole field of duality within geometry proper, and the theory of correlative figures which is destined to occupy a prominent position in the domain of mathematics.

Not unconnected with this is the marvellous extension which the transformation of geometrical figures has received very largely from Cremona and the Italian school, and which in the hands of our countrymen Hirst and the late Professor Clifford, has already brought forth such abundant fruit. In this, it may be added, there lay—dormant, it is true, and long unnoticed—the principle whereby circular may be converted into rectilinear motion, and *vice versâ*,—a problem which until the time of Peaucillier seemed so far from solution, that one of the greatest mathematicians of the day thought that he had proved its entire impossibility.

In the hands of Sylvester, of Kempe, and others, this principle has been developed into a general theory of link-work, on which the last word has not yet been said.

If time permitted, I might point out how the study of particular geometric figures, such as curves and surfaces, has been in many instances replaced by that of systems of figures infinite in number, and indeed of various degrees of infinitude. Such, for instance, are Plücker's complexes and congruencies. I might describe also how Riemann taught us that surfaces need not present simple extension without thickness; but that, without losing their essential geometric character, they may consist of manifold sheets; and thus our conception of space, and our power of interpreting otherwise perplexing algebraical expressions, become immensely enlarged.

Other generalisations might be mentioned, such as the principle of continuity, the use of imaginary quantities, the extension of the number of the dimensions of space, the recognition of systems in which the axioms of Euclid have no place. But as these were discussed in a recent address, I need not now do more than remind you that the germs of the great calculus of Quaternions were first announced by their author, the late Sir W. R. Hamilton, at one of our meetings.

Passing from geometry proper to the other great branch of mathematical machinery, viz. algebra, it is not too much to say that within the period now in review there has grown up a modern algebra which to our founders would have appeared like a confused dream, and whose very language and terminology would be as an unknown tongue.

Into this subject I do not propose to lead you far. But, as the progress which has been made in this direction is certainly not less than that made in geometry, I will ask your attention to one or two points which stand notably prominent.

In algebra we use ordinary equations involving one unknown quantity; in the application of algebra to geometry we meet with equations, representing curves or surfaces, and involving two, or three, unknown quantities respectively; in the theory of probabilities, and in other branches of research, we employ still more general expressions. Now the modern algebra, originating with Cayley and Sylvester, regards all these diverse expressions as belonging to one and the same family, and comprises them all under the same general term 'quantics.' Studied from this point of view, they all alike give rise to a class of derivative forms, previously unnoticed, but now known as invariants, covariants, canonical forms, etc. By means of these, mathematicians have arrived not only at many properties of the quantics themselves, but also, at their application to physical problems. It would be a long and perhaps invidious task to enumerate the many workers in this fertile field of research, especially in the schools of Germany and of Italy; but it is perhaps the less necessary to do so, because Sylvester, aided by a young and vigorous staff at Baltimore, is welding many of these results into a homogeneous mass in the classical memoirs which are appearing from time to time in the 'American Journal of Mathematics.'

In order to remove any impression that these extensions of algebra are merely barren speculations of ingenious intellects, I may add that, many of these derivative forms, at least in their elementary stages, have already found their way into the text-books of mathematics; and one class in particular, known by the name of determinants, is now introduced as a recognised method of algebra, greatly to the convenience of all those who become masters of its use.

In the extension of mathematics it has happened more than once that laws have been established so simple in form, and so obvious in their necessity, as scarcely to require proof. And yet their application is often of the highest importance in checking conclusions which have been drawn from other considerations, as well as in leading to conclusions which, without their aid, might have been difficult of attainment. The same thing has occurred also in physics; and notably in the recognition of what has been termed the 'Law of the Conservation of Energy.'

Energy has been defined to be 'The capacity, or power, of any body, or system of bodies, when in a given condition, to do a measurable quantity of work.' Such work may either change the condition of the bodies in question, or it may affect other bodies; but in either case energy is expended by the agent upon the recipient in performance of the work. The law then states that the total amount of energy in the agents and recipients taken together remains unaltered by the changes in question.

Now the principle on which the law depends is this: 'that every kind of change among the bodies may be expressed numerically in one standard unit of change, viz., work done, in such wise that the result of the passage of any system from one condition to another may be calculated by mere additions and subtractions, even when we do not know how the change came about. This being so, all work done by a system may be expressed as a diminution of energy of that system, and all work done upon a system as an accession of energy. Consequently, the energy lost by one system in performance of work will be gained by another in having work done upon it, and the total energy, as between the two systems, will remain unchanged.

There are two cases, or conditions, of energy which, although substantially the same, are for convenience regarded separately. These may be illustrated by the following example. Work may be done upon a body, and energy communicated to it, by setting it in motion, *e.g.* by lifting it against gravity. Suppose this to be done by a spring and detent; and suppose further the body, on reaching its highest point, to be caught so as to rest at that level on a support. Then, whether we consider the body at the moment of starting, or when resting on the support, it has equally received an accession of energy from the spring, and is therefore equally capable of communicating energy to a third body. But in the one case this is due to the motion which it has acquired, and in the other to the position at which it rests, and to its capability of falling again when the support is removed. Energy in the first of these states is called 'Energy of Motion,' or 'Kinetic Energy,' and that in the second state, 'Energy of Position,' or 'Potential Energy.' In the case supposed, at the moment of starting, the whole of the energy is kinetic; as the body rises, the energy becomes partly potential and partly kinetic; and when it reaches the highest point the energy has become wholly potential. If the body be again dropped, the process is reversed.

The history of a discovery, or invention, so simple at first sight, is often found to be more complicated the more thoroughly it is examined. That which at first seems to have been due to a single mind proves to have been the result of the successive action of many minds. Attempts more or less successful in the same direction are frequently traced out; and even unsuccessful efforts may not have been without influence on minds turned towards the same object. Lastly also, germs of thought, originally not fully understood, sometimes prove in the end to have been the first stages of growth towards ultimate fruit. The history of the law of the conservation of energy forms no exception to this order of events. There are those who discern even in the writings of Newton expressions which show that he was in possession of some ideas which, if followed out in a direct line of thought, would lead to those now entertained on the subjects of energy and of work. But however this may be, and whosoever might be reckoned among the earlier contributors to the general subject of energy, and to the establishment of its laws, it is certain that within the period of which I am now speaking, the names of Séguin, Clausius, Helmholtz, Mayer, and Colding on the Continent, and those of Grove, Joule, Rankine, and Thomson in this country, will always be associated with this great work.

I must not, however, quit this subject without a passing notice of a conclusion to which Sir William Thomson has come, and in which he is followed by others who have pursued the transformation of energy to some of its ultimate consequences. The nature of this will perhaps be most easily apprehended by reference to a single instance. In a steam engine, or other engine, in which the motive power depends upon heat, it is well known that the source of power lies not in the general temperature of the whole, but merely on the difference of temperature between that of the boiler and that of the condenser. And the effect of the condenser is to reduce the steam issuing from the boiler to the same temperature as that of the condenser. When this is once done, no more work can be got out of the engine, unless fresh heat be supplied from an outside source to the boiler. The heat originally communicated to the boiler has become uniformly diffused, and the energy due to that difference is said to have been dissipated. The energy remains in a potential condition as regards other bodies; but as regards the engine, it is of no further use. Now suppose that we regard the entire material universe as a gigantic engine, and that after long use we have exhausted all the fuel (in its most general sense) in the world; then all the energy available will have become dissipated, and we shall have arrived at a condition of things from which there is no apparent escape. This is what is called the 'Dissipation of Energy.'

Prof. Frankland has been so good as to draw up for me the following account of the progress of Chemistry during the last half-century.

Most of the elements had been discovered before 1830, the majority of the rarer elements since the beginning of the century. In addition to these the following five have been discovered, three of them by Mosander, viz.:—lanthanum in 1839, didymium in 1842, and erbium in 1843. Ruthenium was discovered by Claus in 1843, and niobium by Rose in 1844. Spectrum Analysis has added five to the list, viz.:—Cæsium and rubidium, which were discovered by Bunsen and Kirchhoff in 1860; thallium, by Crookes in 1861; indium, by Reich and Richter in 1863; and gallium, by Lecoq de Boisbaudran in 1875.

As regards theoretical views, the atomic theory, the foundation of scientific chemistry, had been propounded by Dalton (1804–1808). The three laws which have been chiefly instrumental in establishing the true atomic weights of the elements—the law of Avogadro (1811), that equal volumes of gases under the same conditions of temperature and pressure contain equal numbers of molecules; the law of Dulong and Petit (1819), that the capacities for heat of the atoms of the various elements are equal; and Mitscherlich's law of isomorphism (1819), according to which equal numbers of atoms of elements belonging to the same class may replace each other in a compound without altering the crystalline form of the latter, had been enunciated in quick succession; but the true application of these three laws, though in every case distinctly stated by the discoverers, failed to be generally made, and it was not till the rectification of the atomic weights by Cannizzaro, in 1858, that these important discoveries bore fruit.

In organic chemistry the views most generally held about the year 1830 were expressed in the radical theory of Berzelius. This theory, which was first stated in its electro-chemical and dualistic form by its author in 1817, received a further development at his hands in 1834 after the discovery of the benzoyl-radical by Liebig and Wöhler. In the same year (1834), however, a discovery was made by Dumas, which was destined profoundly to modify the electro-chemical portion of the theory, and even to overthrow the form of it put forth by Berzelius. Dumas showed that an electro-negative element, such as chlorine, might replace, atom for atom, an electro-positive element like hydrogen, in some cases without much alteration in the character of the compound. This law of substitution has formed a necessary portion of every chemical theory which has been proposed since its discovery, and its importance has increased with the progress of the science. It would take too long to enumerate all the theoretical views which have prevailed at various times during the past fifty years; but the theory which along with the radical theory has exercised most influence on the development of the views now held, is the theory of types, first stated by Dumas (1839) and developed in a different form and amalgamated with the radical theory by Gerhardt and Williamson (1848–1852). It is, however, the less necessary to refer in detail to these views, seeing that in the now prevailing theory of atomicity we possess a generalisation which, while greatly extending the scope of chemical science in its power of classifying known and predicting unknown facts, includes all that was valuable in the generalisations which preceded it. The study of the behaviour of organo-metallic compounds in chemical reactions led to the conclusion that various metallic elements possess a definite capacity of saturation with regard to the number of atoms of other elements with which they can combine, and demonstrated this regularity of atom-fixing power in the case of zinc, tin, arsenic, and antimony. A serious obstacle, however, in the way of determining the true atomicities of the elements was the general employment of the old so-called equivalent weights which were by most chemists confounded with the atomic weights. This difficulty was removed by the rectification of the atomic weights, which, though begun by Gerhardt as early as 1842, met for a long time with but little recognition, and was not completed till the subject was taken up by Cannizzaro in 1858. The law of atomicity has given to chemistry an exactness which it did not previously possess, and since its discovery and recognition chemical research has moved very much on the lines laid down by this law.

Chemists have been engaged in determining, by means of decompositions, the molecular architecture, or *constitution* as it is called, of various compounds, natural and artificial, and in verifying by synthesis the correctness of the views thus arrived at.

It was long supposed that an impassable barrier existed between inorganic and organic substances: that the chemist could make the former in his laboratory, while the latter could only be produced in the living bodies of animals or plants,—requiring for their construction not only chemical attraction, but a supposed 'vital force.' It was not until 1828 that Wöhler broke down this barrier by the synthetic production of urea, and since his time this branch of science, in the hands of Hofmann, Wurtz, Berthelot, Butlerow, and others, has made great strides. Innumerable natural compounds have thus been produced in the laboratory—ranging from bodies of relatively simple constitution, such as the alcohols and acids of the fatty series, to bodies of such complex molecular structure as alizarin (the principal colouring matter of madder), coumarin (the odoriferous principle of the tonqua bean), vanillin, and indigo. The problem of the natural alkaloids has also been attacked, in some cases with more than partial success. Methylconine, which occurs along with conine in the hemlock, has been recently prepared artificially by Michael and Gundelach, this being the first instance of the synthesis of a natural alkaloid. A proximate synthesis of atropine, the alkaloid of the deadly nightshade, has been accomplished by Ladenburg. It seems further probable that at no distant date the useful alkaloids, such as quinine, may also be synthesised, inasmuch as quinoline, one of the products of the decomposition of quinine and of some of the allied bases, has recently been prepared by Skraup by a method which admits of its being obtained in any quantity.

Much also has been done in the way of building up compounds the existence of which was predicted by theory. Indeed the extent to which hitherto undiscovered substances can be predicated is doubtless the greatest triumph achieved by chemists during the past fifty years.

As yet, however, only the statical side of chemistry has been developed. Whilst the physicist has been engaged in tracing, for the gaseous condition at least, the paths of the molecules and calculating their velocities, the chemist, whose business is with the atoms within the molecule, can point to no such scientific conquests. All that he knows concerning the intramolecular atoms, and all that he expresses in his constitutional formulæ is, the particular relation of union in which each of these atoms stands to the others—which of them are directly united (as he expresses it) to other given atoms, and which of them are in indirect union. Of the relative positions in space occupied by these atoms, and of their modes of motion, he is absolutely ignorant. In like manner in a chemical reaction the initial and final conditions of the reacting substances are known, but the intermediate stages—the modes of change—are for the most part unexplained.

The feeling that no number, however great, of successfully solved problems of constitutional chemistry (as at present understood), and no number of syntheses, however brilliant, of natural compounds, could raise chemistry above the statical stage—that the solution of the dynamical problem cannot be arrived at by purely chemical means—has led many chemists to approach the subject from the physical side. The results which the physico-chemical methods, as exemplified in the laws already alluded to of Dulong and Petit, Avogadro, and Mitscherlich, have yielded in the past, offer the best guarantee of their success in the future. And the advantages of many of the physical methods are obvious. Every purely chemical examination—whether proximate or ultimate—of a compound, presupposes the destruction of the substance under examination: the chemist 'murders to dissect.' But observations on the action of a substance on the rays of light, on the relative volumes occupied by molecular quantities of a substance, on its velocity of transpiration in the liquid or gaseous state—these teach us the habits of the living substance. The rays of light which have threaded their way between the molecules of a body have undergone, in contact with these molecules, various specific and measurable changes, the nature and amount of which are assuredly conditioned by the mass, form, and other properties of the molecules: the plane of polarisation has been caused to rotate; a particular degree of refraction has been imparted; or rays of certain wave-lengths have been removed by absorption, their absence being manifested by bands in the absorption-spectrum of the substance. The volumes occupied by molecular quantities are dependent partly on the size of the molecules and partly on that of the intermolecular spaces.

The duty of the physical chemist is to endeavour to co-ordinate his physical observations with the known constitution of compounds as already determined by the pure chemist. This endeavour has in various branches of physical chemistry been to some extent successful. Le Bel has found that among organic compounds those only possess action on the plane of polarised light which contain at least one *asymmetric carbon atom*—that is to say, a carbon atom which is united to four *different* atoms or groups of atoms. The researches of Landolt, of Gladstone, and of Brühl on the specific refraction of organic liquids, have shown that from the known constitution of a liquid organic compound it is possible to calculate its specific refraction. Noel Hartley, in an examination of the absorption-spectra of organic liquids for the ultra-violet rays, has demonstrated that certain molecular groupings are represented by particular absorption-bands, and this line of inquiry has been extended, with very interesting results, to the ultra-red rays by Abney and Festing. It is obvious that these methods may in turn be employed to determine the unknown constitution of substances. The same holds true of the investigations of Kopp with regard to the molecular volumes of liquids at their boiling-points, in which he has established the remarkable fact that some elements always possess the same atomic volume in combination, whereas, in the case of certain other elements, the atomic volume varies in a perfectly definite manner with the mode of combination. This investigation has lately been extended with the best results by Thorpe and by Ramsay. Thermo-chemistry, also, which for a long time, at least as regards that portion which relates to the heat of formation of compounds, consisted chiefly of a collection of single equations, each containing three unknown quantities, is beginning to be interpreted by Julius Thomsen, whose experimental work in this field is well known. Many other methods of physico-chemical research are being successfully prosecuted at the present day, but it would go beyond the bounds of this summary even to enumerate these.

The concordant results obtained by these widely differing methods show that those chemists who have devoted themselves, frequently amid the ridicule of their more practical brethren, to ascertaining by purely chemical methods the constitution of compounds, have not laboured in vain. But the future doubtless belongs to physical chemistry.

In connection with the rectification of the atomic weights it may be mentioned that a so-called natural system of the elements has been introduced by Mendelejeff (1869), in which the properties of the elements appear as a periodic function of their atomic weights. By the aid of this system it has been possible to predict the properties and atomic weights of undiscovered elements, and in the case of known elements to determine many atomic weights which had not been fixed by any of the usual methods. Several of these predictions have been verified in a remarkable manner. A periodicity in the atomic weights of elements belonging to the same class had been pointed out by Newlands about four years before the publication of Mendelejeff's memoir.

In mechanical science the progress has not been less remarkable than in other branches. Indeed to the improvements in mechanics we owe no small part of our advance in practical civilization, and of the increase of our national prosperity during the last fifty years.

This immense development of mechanical science has been to a great extent a consequence of the new processes which have been adopted in the manufacture of iron, for the following data with reference to which I am mainly indebted to Captain Douglas Galton and Mr. Stuart Rendel. About 1830, Neilson introduced the Hot Blast in the smelting of iron. At first a temperature of 600° or 700° Fahrenheit was obtained, but Cowper subsequently applied Siemens' regenerative furnace for heating the blast, chiefly by means of fumes from the blast furnace, which were formerly wasted; and the temperature now practically in use is as much as 1,400° or even more: the result is a very great economy of fuel and an increase of the output. For instance, in 1830, a blast furnace with the cold blast would probably produce 130 tons per week, whereas now, 600 tons a week are readily obtained.

Bessemer, by his brilliant discovery, which he first brought before the British Association at Cheltenham in 1856, showed that Iron and Steel could be produced by forcing currents of atmospheric air through fluid pig metal, thus avoiding for the first time the intermediate process of puddling iron, and converting it by cementation into steel. Similarly by Siemens' regenerative furnace, the pig metal and iron ore is converted directly into steel, especially mild steel for shipbuilding and boilers; and Whitworth, by his fluid compression of steel, is enabled to produce steel in the highest condition of density and strength of which the metal is capable. These changes, by which steel can be produced direct from the blast furnace instead of by the more cumbersome processes formerly in use, have been followed by improvements in the manipulation of the metal.

The inventions of Cort and others were known long before 1830, but we were then still without the most powerful tool in the hands of the practical metallurgist, viz., Nasmyth's steam-hammer.

Steel can now be produced as cheaply as iron was formerly; and its substitution for iron as railway material and in shipbuilding, has resulted in increased safety in railway travelling, as well as in economy, from its vastly greater durability. Moreover, the enlarged use of iron and steel, which has resulted from these improvements in its make, has led to the adoption of mechanical means to supersede hand labor in almost every branch of trade and agriculture, by which the power of production has been increased a hundredfold, while at the same time much higher precision has been obtained. Sir Joseph Whitworth has done more than any one else to perfect the machinery of this country by the continued efforts he has made, during nearly half-a-century, to introduce accuracy into the standards of measurement in use in workshops. He tells us that when he first established his works, no two articles could be made accurately alike or with interchangeable parts. He devised a measuring apparatus, by which his workmen in making standard gauges are accustomed to take measurements to the $\frac{1}{20000}$ of an inch.

In its more immediate relation to the objects of this Association, the increased importance of iron and steel has led to numerous scientific investigations into its mechancial properties and into the laws which govern its strength; into the proper distribution of the material in construction; and into the conditions which govern the friction and adhesion of surfaces. The names of Eaton Hodgkinson, Fairbairn, Barlow, Rennie, Scott Russell, Willis, Fleeming Jenkin, and Galton are prominently associated with these inquiries.

The introduction of iron has, moreover, had a vast influence on the works of both the civil and military engineer. Before 1830, Telford had constructed an iron suspension turnpike-road bridge of 560 feet over the Menai Straits; but this bridge was not adapted to the heavy weights of locomotive engines. At the present time, with steel at his command, Mr. Fowler is engaged in carrying out the design for a railway bridge over the Forth, of two spans of 1,700 feet each; that is to say, of nearly one third of a mile in length. In artillery, bronze has given place to wrought iron and steel; the 68-pound shot, which was the heaviest projectile fifty years ago, with its range of about 1,200 yards, is being replaced by a shot of nearly a quarter-ton weight, with a range of nearly five miles; and the armour-plates of ships are daily obtaining new developments.

But it is in railroads, steamers, and the electric telegraph that the progress of mechanical science has most strikingly contributed to the welfare of man.

As regards railways, the Stockton and Darlington Railway was opened in 1825, but the Liverpool and Manchester Railway, perhaps the first truly passenger line, dates from 1830, while the present mileage of railways is over 200,000 miles, costing nearly 4,000,000,000*l*. sterling. It was not until 1838 that the *Sirius* and *Great Western* first steamed across the Atlantic. The steamer, in fact, is an excellent epitome of the progress of the half-century; the paddle has been superseded by the screw; the compound has replaced the simple engine; wood has given place to iron, and iron in its turn to steel. The saving in dead weight, by this improvement alone, is from 10 to 16 per cent. The speed has been increased from 9 knots to 15, or even more. Lastly, the steam-pressure has been increased from less than 5 lbs. to 70 lbs. per square inch, while the consumption of coal has been brought down from 5 or 6 lbs. per horse-power to less than 2. It is a remarkable fact that not only is our British shipping rapidly on the increase, but it is increasing relatively to that of the rest of the world. In 1860 our tonnage was 5,700,000 against 7,200,000; while it may now be placed as 8,500,000 against 8,200,000; so that considerably more than half the whole shipping of the world belongs to this country.

If I say little with reference to economic science and statistics it is because time, not materials, are wanting.

I scarcely think that in the present state of the question I can be accused of wandering into politics if I observe that the establishment of the doctrine of free trade as a scientific truth falls within the period under review.

In education some progress has been made towards a more rational system. When I was a boy, neither science, nor modern languages, nor arithmetic formed any part of the public school system of the country. This is now happily changed. Much, however, still remains to be done. Too little time is still devoted to French and German, and it is much to be regretted that even in some of our best schools they are taught as dead languages. Lastly, with few exceptions, only one or two hours a week on an average are devoted to science. We have, I am sure, none of us any desire to exclude, or discourage, literature. What we ask is that, say, six hours a week each should be devoted to mathematics, modern languages, and science—an arrangement which would still leave twenty hours for Latin and Greek. I admit the difficulties which schoolmasters have to contend with; nevertheless, when we consider what science has done and is doing for us, we cannot but consider that our present system of education is, in the words of the Duke of Devonshire's Commission, little less than a national misfortune.

In agriculture the changes which have occurred in the period since 1831 have been immense. The last half-century has witnessed the introduction of the modern system of subsoil drainage, founded on the experiments of Smith of Deanston. The thrashing and drilling machines were the most advanced forms of machinery in use in 1831. Since then there have been introduced the steam-plough; the mowing-machine; the reaping-machine, which not only cuts the corn but binds it into sheaves; while the steam-engine thrashes out the grain and builds the ricks. Science has thus greatly reduced the actual cost of labour, and yet it has increased the wages of the labourer.

It was to the British Association, at Glasgow in 1841, that Baron Liebig first communicated his work 'On the Application of Chemistry to Vegetable Physiology,' while we have also from time to time received accounts of the persevering and important experiments which Mr. Lawes, with the assistance of Dr. Gilbert, has now carried on for more than forty years at Rothamsted, and which have given so great an impulse to agriculture by directing attention to the principles of cropping, and by leading to the more philosophical application of manures.

I feel that in quitting Section F so soon, I owe an apology to our fellow-workers in that branch of science, but I doubt not that my short-comings will be more than made up for by the address of their excellent President, Mr. Grant-Duff, whose appointment to the Governorship of Madras, while occasioning so sad a loss to his friends, will unquestionably prove a great advantage to India, and materially conduce to the progress of science in that country.

Moreover, several other subjects of much importance, which might have been referred to in connection with these latter Sections, I have already dealt with under their more purely scientific aspect.

Indeed, one very marked feature in modern discovery is the manner in which distinct branches of science have thrown, and are throwing, light on one another. Thus the study of geographical distribution of living beings, to the knowledge of which our late general secretary, Mr. Sclater, has so greatly contributed, has done much to illustrate ancient geography. The existence of high northern forms in the Pyrenees and Alps indicates the existence of a period of cold when Arctic species occupied the whole of habitable Europe. Wallace's line—as it has been justly named after that distinguished naturalist—points to the very ancient separation between the Malayan and Australian regions; and the study of corals has thrown light upon the nature and significance of atolls and barrier-reefs.

In studying the antiquity of man, the archæologist has to invoke the aid of the chemist, the geologist, the physicist, and the mathematician. The recent progress in astronomy is greatly due to physics and chemistry. In geology the composition of rocks is a question of chemistry and physics; the determination of the boundaries of the different formations falls within the limits of geography; while palæontology is the biology of the past.

And now I must conclude. I fear I ought to apologise to you for keeping you so long, but still more strongly do I wish to express my regret that there are almost innumerable researches of great interest and importance which fall within the last fifty years (many even among those with which our Association has been connected) to which I have found it impossible to refer. Such for instance are, in biology alone, Owen's memorable report on the homologies of the vertebrate skeleton, Carpenter's laborious researches on the microscopic structure of shells, the reports on marine zoology by Allman, Forbes, Jeffreys, Spence Bate, Norman, and others; on Kent's Cavern by Pengelly, those by Duncan on corals; Woodward on crustacea; Carruthers, Williamson, and others on fossil botany, and many more. Indeed no one who has not had occasion to study the progress of science throughout its various departments can have any idea how enormous—how unprecedented—the advance has been.

Though it is difficult, indeed impossible, to measure exactly the extent of the influence exercised by this Association, no one can doubt that it has been very considerable. For my own part, I must acknowledge with gratitude how much the interest of my life has been enhanced by the stimulus of our meetings, by the lectures and memoirs to which I have had the advantage of listening, and above all, by the many friendships which I owe to this Association.

Summing up the principal results which have been attained in the last half-century we may mention (over and above the accumulation of facts) the theory of evolution, the antiquity of man, and the far greater antiquity of the world itself; the correlation of physical forces and the conservation of energy; spectrum analysis and its application to celestial physics; the higher algebra and the modern geometry; lastly, the innumerable applications of science to practical life—as, for instance, in photography, the locomotive engine, the electric telegraph, the spectroscope, and most recently the electric light and the telephone.

To science, again, we owe the idea of progress. The ancients, says Bagehot, 'had no conception of progress; they did not so much as reject the idea; they did not even entertain it.' It is not, I think, going too far to say that the true test of the civilisation of a nation must now be measured by its progress in science. It is often said, however, that great and unexpected as the recent discoveries have been, there are certain ultimate problems which must ever remain unsolved. For my part I would prefer to abstain from laying down any such limitations. When Park asked the Arabs what became of the sun at night, and whether the sun was always the same, or new each day, they replied that such a question was childish and entirely beyond the reach of human investigation. I have already mentioned that, even as lately as 1842, so high an authority as Comte treated as obviously impossible and hopeless any attempt to determine the chemical composition of the heavenly bodies. Doubtless there are questions, the solution of which we do not as yet see our way even to attempt; nevertheless the experience of the past warns us not to limit the possibilities of the future.

But however this may be, though the progress made has been so rapid, and though no similar period in the world's history has been nearly so prolific of great results, yet, on the other hand, the prospects of the future were never more encouraging. We must not, indeed, shut our eyes to the possibility of failure; the temptation to military ambition; the tendency to over-interference by the state; the spirit of anarchy and socialism; these and other elements of danger may mar the fair prospects of the future. That they will succeed, however, in doing so, I cannot believe. I cannot but feel confident that fifty years hence, when perhaps the city of York may renew its hospitable invitation, my successor in this chair—more competent, I trust, than I have been to do justice to so grand a theme—will have to record a series of discoveries even more unexpected and more brilliant than those which I have, I fear so imperfectly, attempted to bring before you this evening, for assuredly one great lesson which science teaches is, how little we yet know, and how much we have still to learn.

REPORTS

ON THE

STATE OF SCIENCE.

REPORTS

ON THE

STATE OF SCIENCE.

Report of the Committee, consisting of Professor SYLVESTER, Professor CAYLEY, *and* Professor SALMON, *for the calculation of Tables of the Fundamental Invariants of Algebraic Forms.*

THE principal work performed by aid of the grant to the Committee during the past year has been the calculation of the irreducible invariants and covariants appertaining to the binary quantics of the 12th order by Mr. F. Franklin, of Baltimore, under the direction of Professor Sylvester. A brief synopsis of the result of this enormous computation is annexed.

TABLE of the GROUND-FORMS to the Binary Octavic Form.

Degree in Coefficients / Orders in Variables	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	34
1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
2	1	—	1	—	1	—	1	—	1	—	1	—	—	—	—	—	—
3	1	—	1	1	2	1	2	2	1	2	1	1	1	1	—	1	—
4	2	—	3	2	4	3	4	4	3	4	2	3	1	2	1	1	1
5	2	2	5	6	7	8	6	9	5	6	3	4	1	1	—	—	—
6	4	4	9	11	12	14	10	12	3	5	—	—	—	—	—	—	—
7	5	10	15	20	18	21	9	8	—	—	—	—	—	—	—	—	—
8	7	16	24	29	21	21	—	—	—	—	—	—	—	—	—	—	—
9	9	28	33	37	15	—	—	—	—	—	—	—	—	—	—	—	—
10	14	39	41	30	—	—	—	—	—	—	—	—	—	—	—	—	—
11	15	53	40	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	19	56	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13	18	44	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
948 =	109	252	179	136	80	68	33	35	13	17	7	8	3	4	1	2	1

Total No. of Ground-forms (counting in the quantic itself and the absolute constant) = 949.

It may be noticed that the highest order in the variables which appears in this table is 34, coinciding with the 'superior limit' furnished by M. Camille Jordan's law; so that in this, as has also been proved to be the case for all the forms of the 10th and lower orders, this so-called limit to the order is the actual highest order itself.

The computation of the ground-forms to the binary quantic of the 11th order, on account of the immense length of the calculations which it would involve, has not been undertaken. It is to be hoped that this may some day be accomplished, as it is probable that the generating function for this case would, like that for the 7th order, reveal some peculiar features not observable in the generating function for quantics, the orders of which are multiples of 2, 3, or 5.

Since the publication of the lists of ground-forms (calculated by aid of the British Association grant) in the 'American Journal of Mathematics,' Dr. Von Gall, of Mainz, has rendered a very important service to algebraical science by applying the German method to the ascertainment of the ground-forms of the binary quantic of the 8th order, and his final results have been brought into perfect accordance with those contained in the lists above referred to, with the exception of one single form of the deg-order 10·4, which he has not been able to decompose, but which ought to be reducible if the fundamental postula e employed in the English method is valid. It became, therefore, a matter of great importance to demonstrate that no ground-form of such deg-order can exist, for this will probably be the last occasion when it will be possible to compare the results obtained by the two methods.

Accordingly, Professor Sylvester, in conjunction with Mr. Morgan Jenkins, has calculated certain of the ground-forms for a particular function of the 8th order, and has thereby been able to demonstrate the impossiblity of the existence of a ground-form of the deg-order in question. This impossibility is made to depend ultimately on the fact that the minor determinants of the 10th order belonging to a matrix 11 places wide and 10 deep do not all vanish, and the correctness of the figures appearing in this matrix is demonstrated by showing that a certain determinant of the 11th order, formed by adding on another line of figures to this matrix, does vanish, which is practically effected by testing its value in respect to various numerical moduli. The calculations have been made independently by Mr. Sylvester and Mr. Jenkins, and concur in proving (to the highest degree of moral certainty) the correctness of the previous work. The non-existence of the doubtful ground-form may accordingly be regarded as now placed beyond all reasonable doubt.

A summary of the method employed, and the calculations to which that method leads, has been sent for insertion in the 'Comptes Rendus' of the Institute of France, and the whole of the work will be reproduced in detail in the forthcoming Number of the 'American Journal of Mathematics.'

Report on Recent Progress in Hydrodynamics.—Part I.

By W. M. Hicks, *M.A.*

At the meeting of the Association at Swansea, last year, I was requested to draw up a report on the recent progress of hydrodynamics. I have interpreted this to extend back to the time of the last report to the Association, in 1846, by Professor Stokes. Though the period is somewhat extended, and necessitates a report perhaps excessively long, yet it seemed to me that this objection would be counterbalanced by the advantage of the different reports to the Association forming a connected series. The period separates itself naturally into three divisions, of about ten years each: from 1846 to the publication of Helmholtz' paper on vortex motion, in 1856; from then to the appearance of Thomson & Tait's 'Natural Philosophy,' in 1866, which introduced a new general method into the treatment of hydrodynamics, by the application of the Lagrangian Equations of Motion; and from the last period up to the present time. I propose to consider the progress under the two heads of (I.) General Theory and (II.) Special Problems, though stress of other engagements has prevented my completing the second part in time for this meeting. I hope, however, to complete it before the next meeting of the Association.

Under each head I have striven to keep as much as possible the historical order in which the subjects have been developed, though, for the sake of continuity, it has sometimes been necessary to deviate slightly from this rule. It has not been an easy matter, out of such a rich field of investigation, to decide what to include and what to leave out; but it is hoped that the most important results obtained during the last forty years will be found referred to, although the report does not pretend to be in any sense a complete bibliography of hydrodynamics. Several subjects, whose boundaries are not sharply defined, have been neglected altogether, as they would almost require reports to themselves; such are, for instance, the theory of sound and tides. The experimental side, also, has not been considered, except in a few cases, in the way of reference. These restrictions have been rendered necessary to keep the length of the report within reasonable bounds.

I. General Theory.

Under this head I propose to notice successively (*a*) treatment of General Equations for a perfect fluid, (*b*) Vortex Motion, (*c*) Discontinuous Motion, (*d*) General Motion of solids in fluid (*e*) Viscosity, (*f*) Waves in liquids.

(*a*) *General Equations of motion of a perfect fluid.*

In 1856, Clebsch published a paper[1] (it is signed 'August, 1854') on the motion of an ellipsoid in fluid. The first part of the paper is devoted to a transformation of the ordinary equations when there is a velocity potential to moving axes, and thence to orthogonal curvilinear co-ordinates. He expresses the surface conditions in terms of the same co-ordinates, and shows that the velocity potential is a linear function of the quantities which would now be called generalised velocities and rotations. He then gives the pressures in the same generalised form,

[1] *Crelle*, 1856.

and shows how they are simplified when the body has three planes of symmetry. For this case he finds the generalised equations of motion in terms of the pressures exerted on the surface of the solid, and considers separately pure translation and pure rotation. Amongst results, he notices that the fluid moves in 'stream lines' (in Fäden), that the effect of the fluid is to cause an apparent increase of mass, different in different directions, a diminution of gravity; and states the following laws:— 'The form of the curves on which the particles of the fluid appear to move relatively to the centre of gravity of the body depends only on the form of the body and the curve on which its centre of gravity moves.' These results had already, several years before, been given by Stokes.[1]

In the next year appeared another paper, by the same author, *On a general transformation of the hydrodynamical equations.*[2] This is exceedingly general, and starts with the consideration of equations analogous to the hydrodynamical equations in n variables, viz.:—

$$\frac{dV}{dx_1} = \frac{du_1}{dt} + u_1 \frac{du_1}{dx_1} + u_2 \frac{du_1}{dx_2} + \ldots + u_n \frac{du_1}{dx_n},$$

&c., together with

$$\frac{du_1}{dx_1} + \frac{du_2}{dx_2} + \ldots\ldots + \frac{du_n}{dx_n} = 0 \quad \ldots\ldots (1)$$

He takes n arbitrary functions $a_0, a_1, \ldots a_{n-1}$, of the variables, forms their Jacobian, and takes the minors of $\frac{da_0}{dx_1}, \frac{da_0}{dx_2}, \ldots$ Calling these $\Delta_1, \Delta_2, \ldots$, they satisfy the equation

$$\frac{d\Delta_1}{dx_1} + \frac{d\Delta_2}{dx_2} + \ldots = 0$$

The transformation now consists in making $a_1 \ldots a_{n-1}$ the dependent variables, being connected with the old ones by the equations $u_1 = \Delta_1$, &c., which is possible, since the equation (1) is satisfied. Introducing the quantity T, defined by the equation $2T = \Delta^2_1 + \ldots + \Delta^2_n$, he proves that the above equations are equivalent to others of the form

$$\frac{d}{dx_1}(V - T) = A_1 \frac{da_1}{dx_1} + A_2 \frac{da_2}{dx_1} + \ldots + \frac{d\Delta_1}{dt} \quad \ldots\ldots (2)$$

where $A_1 \ldots$ are functions of $a_1 \ldots a_{n-1}$. If the motion is steady, these produce

$$V - T = F(a_1 \ldots a_{n-1}),\ A_m = \frac{dF}{da_m}$$

The investigation is necessarily complicated, and the reader is referred, for the full working out, to the paper itself. He shows, amongst other things, that when the motion is steady, the equations are the conditions that $\iint \ldots (T - F)dx_1 \ldots dx_n$ is a maximum or minimum. Introducing the condition $u_1 = \frac{dx_1}{dt}$, &c., he shows that for steady motion, the integrals are $a_1 =$ const: &c., and that these give the lines of motion. After reducing the foregoing results to the case of three variables, he shows how to transform the independent variables to others. Lastly, he applies

[1] 'On some cases of fluid motion,' *Camb. Phil. Trans.*, viii.

[2] *Crelle*, liv.

the theory developed above to the cases of two-dimensional motion, and of symmetrical motion in planes through an axis. In the first case, the a_1, a_2 give—one the planes in which the motion takes place, the other the function introduced by Earnshaw (stream function); in the second case the planes through the axis and Stokes' stream function. It is interesting to see how these functions appear, though introduced in such a different manner from those of Earnshaw and Stokes. The two-dimensional stream function was also employed by Meissel, in a short paper, 'Ueber einen speciellen Fall des Ausflusses vom Wasser in einer verticalen Ebene,'[1] apparently without being acquainted with its previous use by Earnshaw and Stokes. Rankine, also, has used it in his paper on plane water lines,[2] where it enters as expressing the flow across any line.

In the paper above referred to, Clebsch had reduced the case for steady motion to one of making the energy a minimum, but he had not succeeded in obtaining an analogous result for non-steady motion. This question he takes up in a paper, published in Crelle,[3] 'Ueber die Integration der hydrodynamischen Gleichungen,' but attacks the problem in a quite different but original way. He introduces three functions, ϕ, ψ, m, so that $udx + vdy + wdz = d\phi + md\psi$. These can represent any general motion of which a fluid is capable; and the velocities and vortex components, at any point, are given by equations of the form

$$u = \frac{d\phi}{dx} + m\frac{d\psi}{dx}, \text{ \&c.,}$$

$$2\xi = \frac{d\,(m.\,\psi)}{d\,\,(y.\,z)}, \text{ \&c.,}$$

or, expressed in quaternion language, vortex $= \frac{1}{2}\,\mathrm{V}\,\nabla m\,\nabla\psi$. As in the earlier paper, he considers first the general case of any number of variables, but we need only state the result as applicable to hydrodynamics. If V denote the force potential, p the pressure, and ρ the density, the equations make

$$\iiiint \left(\mathrm{V} - \frac{p}{\rho}\right)\, dx\, dy\, dz\, dt$$

a maximum or minimum where

$$\mathrm{V} - \frac{p}{\rho} = \frac{d\phi}{dt} + m\frac{d\psi}{dt} + \tfrac{1}{2}\,(u^2 + v^2 + w^2)$$

and u, v, w are expressed as above.[4] The integrals of the equations $u = \dot{x}$, $v = \dot{y}$, $w = \dot{z}$, are shown to be $m =$ const., $\psi =$ const., and a third. It is clear, from the equation vortex $= \frac{1}{2}\,\mathrm{V}\,(\nabla m.\,\nabla\psi)$, that the vortex filaments are given by the intersections of the surfaces $m =$ const., $\psi =$ const., and its strength is $\frac{1}{2}\,\mathrm{T}\,\nabla m.\,\mathrm{T}\nabla\psi\,\sin\theta$, where θ is the angle between the surfaces, or

$$\tfrac{1}{2}\sqrt{\left\{\left(\overline{\frac{dm}{dx}}\Big|^2 + \overline{\frac{dm}{dy}}\Big|^2 + \overline{\frac{dm}{dz}}\Big|^2\right)\left(\overline{\frac{d\psi}{dx}}\Big|^2 + \ldots\right)\right\}}\,\sin\theta.$$

Between these two last papers of Clebsch, appeared the well-known and remarkable paper of Helmholtz in the same journal[5] on the integrals of the hydrodynamical equations which correspond to vortex motion. This will presently be noticed more fully under vortex motion, but atten-

[1] *Pogg. Ann.*, 95, 1855. [2] *Transactions Royal Soc.*, 1864. [3] *Crelle*, Bd. lvi.
[4] This is really the same as Hamilton's theory of least action. [5] *Crelle*, lv.

tion may be drawn here to the new method by which he expressed the velocities of a fluid in the case of the most general motion by means of functions L,M,N which give the velocities from

$$u = dP/dx + dN/dy - dM/dz, \text{ \&c.}$$

The L,M,N are in reality the tensors of the three rectangular components of a vector, now called a vector potential; in fact, the velocities are here expressed by a quaternion potential. Calling the potential q, the conditions [1] are

$$\nabla^2 Sq = 0 \qquad S\nabla q = 0$$
$$\text{Velocity} = \nabla q \quad = \sigma \text{ (say)}$$
$$\text{Rotation} = \tfrac{1}{2}\nabla^2 q = \tfrac{1}{2}\nabla\sigma$$

For vortex rings symmetrical about an axis, Helmholtz transforms the vector potential into another, which is nothing else than Stokes' stream function for such motions divided by the distance from the axis.

The next great advance in theory was due to the publication in 1867 of Thomson and Tait's 'Natural Philosophy.' Here, for the first time, Lagrange's equations of motion were applied, though without any direct proof that the equations were applicable to cases in which there is an infinite degree of freedom and in which a portion of the generalised co-ordinates do not appear. Objections were raised by several mathematicians to this application, amongst whom may be mentioned Purser [2] and Boltzmann.[3] As a matter of fact the equations are only directly applicable under the conditions mentioned below. In the second edition, published in 1879, this question was considered under a general theory of 'ignoration of co-ordinates.' Starting with the expression for the energy containing all the generalised velocities, the generalised equations for the co-ordinates ignored are written down and integrated once on the supposition that the force components corresponding to the ignored co-ordinates do not occur. These give a number of equations, containing the velocities, equal in number to the ignored co-ordinates, and of the form—linear function of the velocities = constant. By means of these, therefore, the ignored velocities can be eliminated from the expression for the energy. This is done, and Lagrange's equations for the non-ignored co-ordinates are transformed to apply to the energy as expressed in the new form. Naturally this is more complicated than the ordinary Lagrangian form, but when we have to do with fluid motion, where the motion commences from rest, or can be brought to rest without application of force components corresponding to the ignored co-ordinates, the constants introduced in the first integration are all zero. When this is the case the transformed Lagrangian equations reduce to the ordinary form. The half-dozen pages devoted to fluid motion in the first volume have altogether transformed the methods of hydrodynamics, and possibly have been a cause why the papers of Clebsch already referred to have been allowed to fall into neglect.[4]

All the foregoing investigations have proceeded on the method of the so-called Euler's equations, *i.e.* where the velocities at different points of

[1] *Quarterly Journal*, xiv. p. 284.

[2] 'On the applicability of Lagrange's equations in certain cases of fluid motion,' *Phil. Mag.* (5), vi. p. 354.

[3] 'Ueber die Druckkräfte, welche auf Ringe wirksam sind, die in bewegte Flüssigkeit tauchen,' *Borch.* lxxiii. p. 111.

[4] For further notices on the equation of motion see p. 16, below.

the space filled by the fluid are sought in terms of the time and position. We have now to refer to a remarkable simplification introduced into the equations of motion in the 'Lagrangian' form, where the position of any particle at any time is sought in terms of the time and its initial position. This was effected by Weber[1] in 1868. Integrating the equation by parts with respect to the time between the limits o and t, they take the form

$$\frac{dx}{dt}\ \frac{dx}{da} + \frac{dy}{dt}\ \frac{dy}{da} + \frac{dz}{dt}\ \frac{dz}{da} - u_0 = \frac{d\lambda}{da},$$

where $(x\ y\ z)$ is the position of the particle at time t, whose initial position was $(a\ b\ c)$, and whose initial velocities were $u_0\ v_0\ w_0$; where also λ is given by

$$\frac{d\lambda}{dt} = \text{Force potential} - \int \frac{dp}{\rho} + \tfrac{1}{2}\,(\text{vel})^2.$$

In the particular case where the initial velocities have a potential $u_0 + d\lambda/da$, . . . can be written $d\chi/da$, . . . , and the equations with the equation of continuity give four equations to determine the four unknown functions $x\ y\ z$ and χ, of the first order but second degree. This[2] forms an easy proof of the theorem, once a velocity potential, always one.

We have already seen how Clebsch attacked the theory of the general motion of a fluid, by employing three functions ϕ, m, ψ where

$$u\,dx + v\,dy + w\,dz = d\phi + m\,d\psi,$$

and it was pointed out that m and ψ by their intersections give vortex lines. It is clear then that these surfaces must form two families which contain the same particles of fluid at all times. The general problem of taking as independent variables any system of surfaces always containing the same particles was taken up by Mr. Hill,[3] apparently without a knowledge of Clebsch's researches. He starts by taking any three independent sets of such surfaces (say P,Q,R) which must be three independent solutions of the equation

$$\frac{df}{dt} + u\ \frac{df}{dx} + v\ \frac{df}{dy} + w\ \frac{df}{dz} = 0 = \frac{\partial f}{\partial t}.$$

Transforming the equations to independent variables P.Q.R, and taking the circulation round elementary circuits, he shows that

$$u\ dx + v\ dy + w\ dz = f_1\ d\mathrm{P} + f_2\ d\mathrm{Q} + f_3\ d\mathrm{R} + d\mathrm{K}$$

where $f_1\ f_2\ f_3$ are definite functions of P,Q,R. Further, the pressure is given by

$$\frac{p}{\rho} + \mathrm{V} - \tfrac{1}{2}\left(u^2 + v^2 + w^2\right) = -\frac{d\mathrm{K}}{dt}$$

After proving that the vortex lines are the intersections of two surfaces which satisfy $\partial f/\partial t = 0$, Q and R, are chosen to be such. This introduces a considerable simplification and enables us to write the former equation in the form $u\ dx + v\ dy + w\,dz = d\chi + \lambda d\psi$ where $\partial\lambda/\partial t = 0, \partial\psi/\partial t = 0$. The velocities are now in the form given by Clebsch, but the expression for the pressure appears at first sight different. This is not so in reality, as

[1] 'Ueber eine Transformation der hydrodynamischen Gleichungen,' *Crelle*, lxviii.
[2] Lamb's treatise *On the Motion of a Fluid*, p. 18.
[3] 'On some properties of the equations of hydrodynamics,' *Quart. Jour. of Math.* Feb. 1880; vol. xvii.

may be easily shown. In Clebsch's form $d\psi/dt = -(u\psi_x + v\psi_y + w\psi_z)$ since $\partial\psi/\partial t = 0$. Putting in this and substituting for u v w their values, it reduces to

$$\frac{p}{\rho} - \mathrm{V} = -\frac{d\phi}{dt} - \tfrac{1}{2}\left(\phi_x^2 + \phi_y^2 + \phi_z^2\right) + \tfrac{1}{2}m^2\left(\psi_x^2 + \psi_y^2 + \psi_z^2\right)$$

which is the same as Hill's form reduces to, with the sign of V changed, when their values are substituted for u v w. In the latter part of the paper is proved a theorem analogous to Helmholtz' law in vortex motion, as to the constancy of vortex strength × section along a vortex filament.[1] Expressed in quaternion symbols, which enable us to see the meaning much more clearly, if Q,R be the surfaces which by their intersections give the filaments, it is easy to show that

$$(\text{area of section of filament}) \times \mathrm{T\,V}\,(\Delta \mathrm{Q}.\Delta \mathrm{R}) = \text{const.}$$

Combining this with the expression for the vortex $\tfrac{1}{2}\mathrm{V}\,(\nabla m.\nabla\psi)$ given above, and limiting Q.R to the case where they give the *vortex* filaments, Helmholtz' law follows as a case of a more general theorem. A special case of the preceding was worked out by Mr. Craig[2] towards the end of the same year. The case only of steady motion is considered and that only when of the three surfaces two are chosen to give the vortex lines. As this part of the paper is almost the same as Hill's, modified so as to leave out of consideration the unsteadiness of the motion, there is no need to refer to it further here. The latter part of the same paper will be noticed again under vortex motion.

A most powerful method of attacking particular problems in fluid motion is that known as the method of images. The conception appears to have been first introduced by Stokes[3] in 1843, in considering the problem of the motion of a sphere in presence of a plane, but the theory received no extension until Thomson's discovery of the electrical image of a point of electricity in presence of a conducting sphere again drew Stokes' attention to the matter, the result being a short note in the 'British Association Report' for 1847, in which he gives the image in a sphere of a doublet whose axis passes through the centre of the sphere. The general cases for a source of fluid and for a doublet with its axis in any direction have been published by the writer,[4] and for a vortex by Mr. Lewis.[5] The images in two dimensions for a circle have been long known, but I have not been able to discover by whom first used. The images for ellipses are also known.[6] These will be referred to again under the head of special problems.

Maximum and Minimum Theorems. Uniqueness of Solution, &c.

Before going further, it may be well to refer here to one or two points in the history which are of importance and which have not yet been touched upon. It has been shown how Clebsch deduced a maximum and minimum theorem on the equations of motion; but the first, so far as I am aware, to give any such general theorem peculiar to hydrodynamics,

[1] It is not stated quite correctly, as he speaks of the product of a vector and an area being constant, instead of the tensor of a vector.

[2] 'Methods and results. General properties of the equations of steady motion,' *United States Coast and Geodetic Survey.* Washington, 1881.

[3] 'On some cases of fluid motion,' *Camb. Phil. Trans.*, viii.

[4] 'On the motion of two spheres in a fluid,' *Roy. Soc. Trans.*, pt. ii. 1880.

[5] 'On the images of vortices in a spherical vessel,' *Quart. Jour.*, xvi.

[6] 'On functional images in ellipses,' *Quart. Jour.*, xvii.

was Thomson,[1] in 1849. The theorem as enunciated by him is, 'If the bounding surface of a liquid primitively at rest be made to vary in a given arbitrary manner, the *vis-viva* of the entire liquid at each instant will be less than it would be if the liquid had any other motion consistent with the given motion of the bounding surface.' This theorem was afterwards, in Thomson and Tait's 'Natural Philosophy,' extended to dynamical problems in general. From this theorem, he states three corollaries—(1) The condition that $udx + vdy + wdz$ must be a complete differential is, in addition to the kinematical conditions, sufficient to determine the motion. (2) The motion of the fluid at any time is independent of the preceding motion, and depends solely on the given form and normal motion of the bounding surface at the instant. (3) If the bounding surface be brought to rest, the liquid will at the same instant be reduced to rest. None of the theorems contained in these corollaries were new. But the first corollary forms, I believe, the first definite proof of the uniqueness of the solution obtained when the fluid is irrotational and the normal motion of the surface is given. Former writers, though convinced of its truth, had not succeeded in arriving at a formal proof of it. In 1843, Stokes[2] writes that it is a recognised principle, that when a problem is determinate, any solution which satisfies all the requisite conditions is the solution of the problem; and then states that the problem is determinate—a proof based on experiment. The second and third are also proved by Stokes in the same paper, and by Cauchy.[3] The theorem that the velocity cannot be a maximum at any point of the fluid was given by Maxwell[4] in a Senate House paper, and in his lectures at Cambridge, though not stated in the hydrodynamical form. Thomson also gives the now well-known application of Green's theorem to the energy of irrotational motion within a boundary. The analogous expressions for the energy, and its variation with the time in the case of rotational motion, were given by Helmholtz in his vortex paper, and for irrotational motion in multiply continuous space by Thomson.[5]

(*b*) *Vortex Motion.*

During the last forty years, without doubt, the most important addition to the theory of fluid motion has been in our knowledge of the properties of that kind of motion where the velocities cannot be expressed by means of a potential. Certainly, before this we knew something. Stokes' researches had shown the kinematical nature of the motion—the rotation of its small parts[6]—and we also knew that it

[1] 'Notes on Hydrodynamics,' *Camb. and Dubl. Math. Jour.* iv. p. 90.

[2] 'On some cases of fluid motion,' *Camb. Phil. Trans.* viii.

[3] 'Mém. sur la Théorie des Ondes,' *Mém. des Sav. Étrangers* (1827).

[4] Sen. Ho., Thursday afternoon, 1873.

[5] 'Vortex motion,' *Roy. Soc. Edin. Trans.*, xxv.

[6] 'On the theories of the internal friction of fluids in motion,' &c., *Camb. Phil. Trans.* viii.

As to the true nature of this rotation, reference may be made to a discussion between Helmholtz and Bertrand in the *Comptes Rendus*, lxvi. and lxvii (1868). Bertrand's objection reduced itself to a question of the use of the word rotation. The nature of the small displacements of a continuous medium are very fully treated in Thomson and Tait's *Natural Philosophy*. The reader who desires to enter more fully into the theory of the above laws will find much to interest him in the following papers, not mentioned in the text:—

E. J. Nanson, *Messenger of Math.*, (2), iii. p. 120 and (2) vii. p. 182.
C. W. Merrifield, Ibid. (2) iv. p. 105
H. Lamb, Ibid. (2) vii. p, 41, shows the connection between Helmholtz's and Thomson's methods of proofs.

could not be set up or destroyed by a system of conservative forces; but this was almost all. Helmholtz first gave us clear conceptions in his well-known paper[1] referred to above. He introduced the idea of vortex-lines (curves whose tangents at any point coincide in direction with the axis of rotation at that point), and vortex-filaments (the portions of fluid in a tube whose surface is generated by vortex-lines passing through an infinitely small curve). Helmholtz' laws are then proved—(1) Each vortex remains continually composed of the same elements of fluid. (2) The product of the section at any point of a filament into the magnitude of the rotation at the point is constant for all time and for all points of the filament. Also (3) a vortex-filament must be closed or have its ends on the boundary of the surface. The next part of the paper is devoted to finding expressions for the velocity when the rotations at every point of the fluid are known; in other words, to finding solutions of the four differential equations.[2]

$$\left.\begin{aligned} \frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} &= 0, \\ \frac{dw}{dy} - \frac{dv}{dz} &= 2\xi, \text{ \&c., \&c.} \end{aligned}\right\}$$

which reduce to three on account of the relation

$$d\xi/dx + d\eta/dy + d\varsigma/dz = 0$$

supposed existing between the given quantities ξ, η, ς. The introduction of the functions L, M, N, has been noticed above. It is shown that they are the potential functions of distributions of magnetic matter, whose density at any point is $\xi/2\pi$, $\eta/2\pi$, $\varsigma/2\pi$, and thence that each rotating element of fluid (a) implies in each other element (b) of the same fluid a velocity which follows the same law as the force exerted on a particle of magnetism at (b) by the element of an electric current at (a), in the axis of rotation.

In the same paper, examples are given of the motion of the fluid due to infinite straight vortices and to circular vortex-filaments. It must be remembered that the results here given refer to the cyclic motion of the fluid as determined by the supposed distribution of magnetic matter, and do not give the most general motion possible. Helmholtz shows that this motion in the case of straight parallel vortices is such that, regarding their strengths as positive or negative masses, according as they rotate in one or the other direction, their centres of gravity remain at rest. When two vortices are of equal and opposite strength they move forward together with constant velocity and at a constant distance. This solves also the case where a single vortex is in a fluid bounded by an infinite plane, to which it is parallel. The results for circular rings are more complicated, and since in nature the section must be finite, an indeterminateness enters on account of the distribution of rotation within it.

N. Jonkoffsky, *Moscauer Math. Samml.* viii.
E. Beltrami, 'Sui principi fondamentali dell' idrodinamica,' *Mem. di Bologna*, i. ii. iii. v.
The two latter treat systematically the kinematics of the motion. Beltrami, amongst other things, compares the motion of an element of fluid with what it would have been if suddenly solidified, and the loss of energy thereby.

[1] *Crelle*, lv., translated in *Phil. Mag.* (4) 33, p. 485.

[2] Helmholtz employs the opposite sign for ξ, η, ζ.

The problem to determine this distribution, so that the motion shall be steady and the ring remain of the same mean size and shape, is one of extreme difficulty and has not yet been successfully attempted. If we regard a ring whose axial section is small, compared with the radius of the axis, he shows that a single such ring moves forward, with approximate constant aperture, with very great velocity in the direction of the fluid motion through the ring itself. When there are two on the same axis, and rotating in the same direction, they travel in the same direction and thread each other alternately. If they have equal and opposite rotations, they approach one another indefinitely, and widen indefinitely as they do so. This is the case of a ring whose plane is parallel to an infinite rigid plane in a fluid. But it is to be remarked that, as stated thus, it is only partially true. This is clearly only the case when the fluid motions through the rings are directed towards each other. If they are directed from each other, they will move from each other, contracting as they do so to a certain limiting radius, which is determinate in terms of any simultaneous radius, strength, and distance.[1]

The permanent character of vortex motion in a perfect fluid has suggested to Sir W. Thomson[2] a theory of the constitution of matter in which atoms consist of small vortex-rings, whose axes may be knotted into any degree of multiple continuity, the beknottedness (as Tait calls it)[3] being a permanent character of the atom. The lines of its spectrum would thus depend on the vibrations of the atom, either of the section or axis. In the paper in which this speculation was brought forward, Thomson notes how the motion of the fluid may be set up by a surface impulse over a diaphragm, across the opening of the ring. The ring will carry forward with it a mass of fluid in irrotational motion, and the whole impulse of the motion is equal to the resultant impulse on the diaphragm. These ideas of the impulse of the motion, and the generation of cyclic motion, were worked out more fully in a paper presented to the Royal Society of Edinburgh, of which only a fragment[4] has been published. In the latter part of this paper, the principles of vortex motion are developed in a quite different way from that followed by Helmholtz, viz., from the fundamental proposition that the 'circulation' in a circuit in the fluid is the same for all circuits which can be continuously deformed into one another without leaving the irrotational part of the fluid. From this all the known theorems are easily deduced. Amongst fresh results may be mentioned the proof that the motion of a liquid moving irrotationally within an $n + 1$ ply connected space is determinate when the normal velocity at every point of the boundary and the values of the circulation in the n circuits are given; and the theorem that the circulation round any closed curve in the fluid is equal to twice the surface-integral of the resolved part of the vortices perpendicular to

[1] For very interesting practical illustrations, the reader is referred to the following papers, by W. B. Rogers:—*American Journal of Science and Art* (2), xxvi. p. 246. This was published in 1858, without knowledge of Helmholtz's mathematical researches. Reusch, *Pogg. Ann.* cx. p. 309 (1860); Osborne Reynolds, *Nature*, xiv. p. 477 (1876), also *Proc. Royal Institution*, viii. p. 272; Oberbeck, *Wied. Ann.* ii. p. 1 (1877): This deals with jets, but contains interesting examples of the formation of rings by incipient jets; R. S. Ball, *Transactions of the Royal Irish Academy*, xxv. p. 135.

[2] 'Vortex Atoms,' *Proc. Roy. Soc. Edin.*, vi. p. 94 (1867); *Phil. Mag.* (4) 34.

[3] 'On Knots,' *Trans. Roy. Soc. Edin.*, xxviii. p. 145.

[4] 'Vortex Motion,' *Trans. Roy. Soc. Edin.* xxv. (1860).

the surface over any surface whose boundary is the curve. This gives at once Helmholtz's theorem that the surface-integral of the same quantity over any closed surface is zero. Looking at the general question of the production of cyclic motion, and noticing that the diaphragm closing the aperture of a ring may be of any shape, it is easy to see that the impulse of the motion of a closed filament of infinitely small section is the resultant of a uniform distribution of pressure (= cyclic constant) over three plane areas which are the projections of the core of the ring on any three planes at right angles.

The general question of the steady motion and stability of vortex-rings has also been considered by Sir W. Thomson in a paper before the same Society, of which, unfortunately, only an abstract[1] has been published. The theory is based on the proposition (only to be stated for its truth to be evident,) that if when the vorticity[2] and impulse are given the kinetic energy is a maximum or minimum, the motion is steady and stable; if it is a maximum-minimum (minimax), the motion is steady, but may be stable or unstable. Unfortunately, the simple circular Helmholtz ring has its energy a minimax, so that from this it is not possible to rigorously decide the question of its stability for all possible displacements, although when the aperture is not too small compared with the section of the core, experiment would lead us to believe that it is stable. For displacements, symmetrical about its axis, it is clear that for some determinate distribution of the vorticity the energy must be a maximum, and the motion stable. Very interesting too are the illustrations given of the steady motion of non-plane vortex-filaments. When the number of twists in the axis of a vortex is large, the core is approximately a helix wound on a circular tore, and approximate expressions are obtained in this case for the radii of the axis and section of the tore in terms of the number of twists, the circulation and the components of the given impulse.

The method introduced of considering the question of stability as a problem of maximum and minimum energy enables us to arrive at many general results which at first sight appear very remarkable, as, for example, the complete annulment of the energy in certain cases by operations on the boundary alone. An extremely interesting illustration of the transformation of a vortex motion with stability of maximum energy to one with stability of minimum energy by operations on the boundary alone, which withdraw energy, was given by the same author before the British Association at its meeting at Swansea[3] in 1880. Approaching the subject from another point of view Lamb[4] had proved that in steady motion it is possible to draw a system of surfaces, each of which is covered by a network of vortex lines and stream lines, and that between any two near surfaces of the system $q\ \omega\ \sin\theta.\ \nu$ is constant where q denotes the velocity along a stream line, ω is the rotation, θ the

[1] 'Vortex Statics.' *Proc. Roy. Soc. Edin.*, ix. p. 59; and *Phil. Mag.*, (5) x. p. 97.

[2] The 'vorticity' of a vortex is given, when supposing it analysed into an infinite number of infinitely small filaments, the volume of each filament and its circulation are given. This does not suppose that the *arrangement* of the filaments is given.

[3] 'On maximum and minimum energy in vortex motion,' *British Association Reports* for 1880, p. 473; also *Nature*, xxii. p. 618. See also a practical illustration, given at the same meeting of the British Association, 'On an experimental illustration of minimum energy in vortex motion,' *Brit. Ass. Rep.*, 1880, p. 491; and *Nature*, xxiii. p. 69.

[4] 'On the conditions of steady motion of a fluid,' *Proc. Lond. Math. Soc.* ix. p. 91 (1878).

angle between q and ω, and ν is the normal distance at the point of the two surfaces.

The problem of the most general vibration of a straight columnar vortex of constant vorticity has been treated by Thomson.[1] If fluid be revolving irrotationally in a fixed cylinder, there will be a cylindric space along the axis, either empty, or filled with fluid in rotational motion. In the former case, suppose the surface disturbed so that the generating lines and normal sections are deformed into harmonic curves of different wave-lengths, the wave-lengths of the cross section being of course sub-multiples of the undisturbed circumference. Then Thomson shows that two velocities of propagation are possible, of the form—angular velocity $= w\ (i \pm \sqrt{N})/i$ where w is the angular velocity of points on the inside surface of the fluid, i is the number of crests in a normal section, and N depends only on the number of crests in unit length along a generating line. One set, therefore, travels in the same direction as the rotation, the other in the same or opposite direction, according to the magnitude of N. For the special case, where the containing vessel is infinitely large, and the distance between the crests on a generating line large compared with the circumference of the hollow $N = 1 + k^2$ ($\cdot 1159 - \log k$) where k denotes this ratio. Here the slow wave for the case $i = 1$ travels in the reverse direction to the rotation. Of more importance than the foregoing is the case of the small vibrations of a vortex column in an infinite irrotationally moving liquid. The periodic times for given harmonic initial disturbance are given by the roots of a transcendental equation, which has an infinite number of roots. This is much simplified when the disturbance is only longitudinal. When the distance between successive swellings of the core is large compared with the circumference, the velocity of propagation corresponding to the smallest root is about $\frac{5}{6}$ of the circular velocity at the surface of the vortex. When there is no longitudinal displacement, the angular velocity of sectional waves is $(i - 1)$ $\times$ ang. vel. of the vortex, where i denotes as before the number of crests on the circumference. The time of pulsation of a hollow vortex enclosed in a flexible cylindrical shell, over whose surface the pressure is constant has been given by the writer.[2]

Mr. F. D. Thomson [3] has proved an interesting theorem relating to a steady motion within cylindrical surfaces. Suppose a cylindrical vessel, of any sectional form, and the contained fluid to be rotating as a rigid body, and that the vessel itself is suddenly brought to rest, then the resulting motion of the fluid will be steady. Another proof has been given by Stokes,[4] but it is easily seen to be a consequence of the uniform distribution of vorticity and Helmholtz' laws.

Quite lately, two papers have been published respectively by Craig[5] and Rowland[6] almost simultaneously. They both seem to have been struck by the fact that if the same operations are performed on the components of rotation that are performed on the components of velocity to deduce the rotations, functions are obtained which satisfy the equation of

[1] 'Vibrations of a columnar vortex,' *Phil. Mag.* (5), x. p. 155.
[2] *Proc. Camb. Phil. Soc.*, iii. p. 283.
[3] 'Some cases of fluid motion,' *Ox. Cam. Dub. Mess. Math.* iii. p. 238, iv. p. 37.
[4] Reprint, vol. i. p. 7 (1880).
[5] 'Methods and results, &c.' *United States Coast Survey*, *Washington*, 1881.
[6] 'On the motion of a perfect incompressible fluid when no solid bodies are present,' *Amer. Jour. of Math.* iii. p. 226.

continuity, and they are thus led to introduce what they call *different orders* of motion. The functions produced after n such operations give the *n th order* of motion. If the functions of the *n th* order are expressible by means of a scalar potential, then the functions of a higher order do not occur. Looked at from the point of view as an investigation of the distribution of vorticity in a fluid motion whose vector-potential is given, it may be possibly of some value, but I cannot help thinking that both Prof. Rowland and Dr. Craig have somewhat overvalued its importance.[1]

(c) *Discontinuous Motion. Jets.*

In a fluid in motion the pressure is, in general, given as a continuous function of position, and may, therefore, so far as the analytical treatment is concerned, become zero or negative. But, in this case, clearly, the fluid will cease to be continuous, and free surfaces will be set up inside the fluid,[2] or surfaces on the two sides of which the tangential motions are different. It is curious that so evident a fact as this seems not to have been noticed by mathematicians in general until it was pointed out by Helmholtz,[3] in 1868, though Stokes[4] had drawn attention to it twenty years before. He had already, in his before-mentioned paper on vortex motion, considered, in passing, the case where the tangential motions are different on the two sides of a surface, and had shown how the motions ought to be represented mathematically, by supposing the surface a continuous vortex-sheet, the vortex-axis at any point being parallel to the resultant of the two tangential velocities. In the later paper he points out that wherever fluid is flowing across a sharp edge, the velocity at the point, on the ordinary theory, would be infinite, and the pressure negative infinity, consequently a surface of separation be established. This would also be the case with gases; but a curious exception occurs, provided they obeyed Boyle's law alone, and did not change their temperature on account of change of volume. Here $\log p$ takes the place of p, and, clearly, $\log p$ may become negative without necessitating a break of continuity in the fluid. This paper is particularly important, as containing the first successful attempt at the solution of a problem where discontinuity ensues. It is evident that along any surface of discontinuity the pressures on both sides must be the same; and if the fluid on one side be at rest, under the action of no

[1] The results are most easily proved and their meaning most clearly seen by the quaternion method. If q be the quaternion potential, σ the velocity, then (*Q. Jour. Math.* xiv. p. 284),

$$\nabla^2 Sq = 0 \quad S\nabla\sigma = 0 \quad \sigma = \nabla q \quad = \rho_0$$
$$2\rho = \nabla\sigma = \rho_1 \quad \text{whence} \quad S\nabla\rho_1 = 0$$
$$\text{and} \quad \rho_n = V\nabla\rho_{n-1} = \nabla^n\sigma \quad , \quad S\nabla\rho_n = 0$$

Also if ρ_n is derivable from a scalar potential $\nabla\rho_n = 0$, or all successive orders must vanish. The only question now of any interest seems to me to be the investigation of the effect on the nature of the motions when the n^{th} operation gives zero result; but whether this is important remains doubtful.

[2] Thus consider a sphere in motion, in an infinite non-gravitating fluid, whose surface is under a constant pressure. The fluid will move in the well-known manner, and the sphere with constant velocity, provided the velocity be not greater than $\sqrt{2p/\rho}$. If it is greater, there will be a hollow formed in the rear until the sphere has been reduced to this limiting velocity.

[3] 'Ueber discontinuirliche Flüssigkeitsbewegungen,' *Monatsb. der k. Akad. Berl.*, 1868, p. 215, translated in the *Phil. Mag.* (4), 36, p. 337.

[4] 'On the Critical Values of the Sums of Periodic Series,' *Cam. Phil. Soc. Trans.*, viii. p. 533, or reprint, p. 310.

external forces through its mass, or if there be no fluid, the pressure along the surface must be constant, and, therefore, also the velocity. Helmholz illustrates this by considering the function $x + yi = A\{\phi + \psi i + exp(\phi + \psi i)\}$. This gives the lines of flow of electricity in an infinite conducting sheet, in which two parallel non-conducting lines are drawn stretching from the points $(-A, \pm A\pi)$ to $-\infty$. It is, therefore, the solution, *so far as the equation of continuity is concerned*, for fluid flowing from between two infinite parallel walls into an infinite fluid; but the conditions at the mouth break up the fluid. He then, by adding $\sigma + \tau i$, a function of $\phi + \psi i$, to the former expression, determines σ, τ, so that when $\psi = \pm\pi$, the velocity may be constant along the free surface. The value obtained is

$$\sigma + \tau i = Ai\,[\surd\{-2\,exp\,\overline{\phi + \psi i} - exp\,2\,(\phi + \psi i)\} \\ + 2\sin^{-1}\{i\surd\tfrac{1}{2}\,exp\,(\phi + \psi i)\}].$$

It is then easy to show that the expression for $x + yi$ gives the motion from an infinite fluid into a canal with parallel walls, extending to infinity in the negative direction. At a great distance from the entrance, in the canal, the fluid tends to flow in a stream whose breadth is half that of the canal.

In Helmholtz' example it seems a happy chance by which a suitable function is found. Kirchhoff[1] remedied this want of method, to some extent, in a paper which contains several further examples of discontinuous motion. Denoting by z the complex $x + yi$, and by w, $\phi + \psi i$, the conditions are—for the rigid boundaries, $\psi =$ constant; and, for the free boundary, $\psi =$ same constant, and the velocity constant. To this end he puts

$$\frac{dz}{dw} = f(w) + \surd\{(fw)^2 - 1\}$$

and chooses $f(w)$, so that for a certain value of ψ, and a certain interval of ϕ, $f(w)$ is real, and lies between the limits $+1$ and -1. For these values, then,

$$\frac{dx}{d\phi} = f(w), \frac{dy}{d\phi} = \surd\{1 - (fw)^2\}$$

or the velocity is constant, and equal to unity. The equation in dz/dw will always give w as a many-valued function of z; now the region of z is the space occupied by the fluid, and since in this space one branch of the function must not pass over into another, the region must be so chosen that within it $f(w)$ is single-valued, or, if it is not so, it must be made so by cuts from the branch points to infinity, along $\psi =$ const., and again $\surd\{(fw)^2 - 1\}$ made single-valued by cuts from its branch points, along the curves $\psi =$ const. through them. The boundary of the region of w consists, then, of lines $\psi =$ const., and $\phi = -\infty$ to $\phi = +\infty$, and within it $f(w)$ must nowhere be infinite. In this case the lines ψ will be stream lines, parts of which form rigid walls, and the other parts free surfaces. In his treatise on mechanics,[2] he has introduced the subject in a slightly different and improved manner. The dz/dw of the foregoing represents the inverse velocity at the point z; hence, along a *straight* rigid boundary, $\varsigma = dz/dw$ is constant in *direction*, whilst along a free surface it is constant in *magnitude*; in other words, as z moves along a bounding

[1] 'Zur Theorie freier Flüssigkeitsstrahlen,' *Crelle*, lxx. p. 289.
[2] *Vorlesungen über mathematische Physik.* Leipzig.

stream line, ς describes a broken path, viz., a curve, which corresponds to the rigid walls; and part of a circle, which corresponds to the free surface. For the region of w are taken two constant values of ψ, and ϕ varying between $-\infty$ and $+\infty$. The boundary of ς chosen is a crescent, one of whose arcs has its centre at the origin, and is to correspond to the free surfaces. Marking on this the points which correspond to the infinite branches of the walls and free surfaces respectively, the points of the crescent will correspond to the ends of the walls where ς changes from a given direction to a given magnitude. The problem now is to find the relation between ς and ω, that the regions of ς, ω may be transformed into one another, so as to be similar in their corresponding small elements. Several extremely interesting problems are solved in these two papers.[1]

In one case only Kirchhoff determined the pressure exerted per unit of length of an infinitely long plane strip immersed perpendicular to a stream, but this is the only practical application he makes of his results. Lord Rayleigh[2] has deduced several most interesting conclusions by means of Kirchhoff's formulæ. He finds expressions for the mean pressure on a lamina held obliquely in a stream, and the position of the centre of pressure. The distance of the centre of pressure from the middle is $\frac{3}{4}\, l \cos \alpha \;/\; (4 + \pi \sin \alpha)$, where α is the inclination of the plane of the lamina to the direction of the stream. For $\alpha = 0$; this divides the breadth in the ratio 11:5; consequently, a blade swinging about an axis nearer the front edge than 5/11 the breadth will be in stable equilibrium; if further from the front edge, the stable positions of equilibrium will be inclined at angles α, on either side, given by the above formula; whilst, if pivoted at the centre, the only position is perpendicular to the stream. He finds that the greatest pressure transverse to the stream is for an inclination nearly equal to 39°.

The problem of the vena contracta is a very old one, and is a case of the discontinuous motion we have been noticing. Hanlon[3] and Maxwell[4] have applied the principle of momentum to its consideration; the former deduced that the contraction must be ·5, whilst the latter showed that it must slightly exceed this. Rayleigh,[5] by slightly varying the circumstances, and supposing the fluid issuing from a nozzle of sufficient length projecting into the fluid, has deduced that, for this case, the coefficient of contraction is almost exactly ·5. Considering also the case of fluid issuing from a finite cylinder through a similar nozzle, he has shown that the section of the nozzle is a harmonic mean between the sections of the cylinder and the jet.

It is by no means easy to illustrate rigorously, by experiment, all the results deduced from the foregoing theory; for, apart from the extreme instability which is a general characteristic of jets and allied motions, other disturbing influences arise from capillary action, in the case of jets into another fluid or vacuum, which tends to break up a column into drops, and from fluid friction, even in the case of two portions of the same fluid moving past each other, where the influence of surface-tension

[1] See under special problems.

[2] British Assoc., Glasgow; also, 'On the Resistance of Fluids,' *Phil. Mag.* (5) ii. p. 430.

[3] 'The Vena Contracta,' *Proc. Lond. Math. Soc.*, iii. p. 4.

[4] Remarks on the preceding paper, *ib.*, p. 6.

[5] 'Notes on Hydrodynamics,' *Phil. Mag.* (5) ii. p. 441.

would not be felt. Experimentally the subject has been very fully investigated,[1] but no attempt has been made towards a general theoretical investigation of the stability of such motions. Lord Rayleigh has, indeed, considered some general aspects of the question in two important papers, in the 'Proceedings of the London Mathematical Society,'[2] some of the results of which it may be well to state here. In the first, he shows that, in the case of cylindrical columns, the disturbing cause due to surface-tension has most effect when, for harmonic disturbances, the ratio of wave-length to diameter is about 4·508; and also determines the rate of falling away from steadiness for small harmonic disturbances in the cases of plane and cylindrical sheets of discontinuity. The results lead to the supposition, as is pointed out in the second paper, that the sensitiveness of sensitive jets would increase indefinitely with the pitch, which is not, in general, true. The explanation he finds in the operation of the viscosity of the fluid, which, for water, is found to be such that, if a plane surface of discontinuity existed at any moment, then, after the lapse of one second, there would be a layer of transition, consisting of vortex motion, of a thickness of half a centimeter. In this paper the fluid is treated as frictionless, but the jets as containing vortex motion, and in two dimensions. For a layer of given thickness, with velocities V and $-$V on the two sides, and uniform vorticity between, the motion is unstable when the wave-length of disturbance is great in comparison with the breadth, and stable when the wave-length is small. For a jet in fluid, at rest, with its centre moving with velocity V, and velocity decreasing uniformly to zero on either side, the motion is stable for symmetrical disturbances, or when the wave-length is small compared with the breadth of the jet, and unstable when it is great. In general, in a case where the velocity increases continually or decreases continually between the fixed boundaries of the fluid, a jet will be stable.

Another kind of discontinuous motion, viz., the propagation of a shock through a slightly compressible liquid, has been treated by Christoffel,[3] in a manner founded on that of Riemann. In such a case there will be a surface of discontinuity in the fluid, which moves forward, and such that the pressure, density, and velocity are different on the two sides. If ω be the normal velocity of progression of a point of the *surface*, Ω_1, ρ_1, Ω_2, ρ_2, the normal velocities and densities of the *fluid* on the two sides, then the equation of continuity is

$$\rho_1(\Omega_1 - \omega) = \rho_2(\Omega_2 - \omega),$$

and it is easily shown that the dynamical equations are three of the form—

$$\rho_2(\Omega_2 - \omega)(u_1 - u_2) + (p_1 - p_2)\cos\alpha = 0,$$

where $u.v.w$ are components of Ω. α, β, γ its direction and p the pressure.

[1] See chiefly Savart, *Ann. de Chimie et de Physique*, liv. lv.; and Magnus, *Pogg. Ann.*, lxxx. xcv. cvi.; also *Phil. Mag.* (4) i. A very full historical account is given by Plateau, in his *Statique expérimentale et théorique des liquides*, tome ii. ch. xii. to which the reader is referred. Since the appearance of this, Oberbeck has published a paper on the same subject, in *Wied. Ann.* ii. p. 1 (1877); and Ridout, *Nature*, xviii. p. 604. See also *Encyc. Brit.* Art Hydraulics by W. C. Unwin.

[2] 'On the Instability of Jets,' *Proc. Lond. Math. Soc.*, x. p. 4; 'On the stability or instability of certain fluid motions,' *Ib.* p. 57.

[3] 'Untersuchungen über die mit dem Fortbestehen linearer partieller Differentialgleichungen verträglichen Unstetigkeiten.' Brioschi, *Annali di Matematica*, viii. p. 81.

These equations are made linear on the supposition that the compressibility is small, and so that if $\rho = \rho_0 (1 + s)$ and $p = p_0 + \rho_0 a^2 s$, quantities of the order $1/a$, and $s\Omega$ are neglected. It follows easily that every point of the surface progresses with a velocity a, so that different positions of the surface at different times form a system of parallel surfaces. Supposing the hydrodynamical equations to hold on both sides and up to the surface of discontinuity, he then shows how to determine the function $S = s_1 - s_2$ on which the solution for Ω depends. In the latter part of the paper reflection at a rigid wall is considered. Rankine[1] has also touched on the same theory.

(*d*) *General Theory of the Motion of Solids in Fluid.*

Already, in 1843, had Stokes[2] proved that if a body symmetrical with respect to two planes at right angles to each other moved in a fluid parallel to their intersection under the action of no forces the resultant pressure of the fluid on it would vanish, provided the body and fluid were originally at rest—in other words, that there is no rotational motion in the fluid. If, on the contrary, its motion were accelerated, it would experience a resultant pressure equal to $n \times$ acceleration $\times$ mass of fluid displaced by the body, where n depends alone on the *form* of the body and not its size. A special case of this was also proved in 1854 by Hoppe,[3] apparently without knowledge of Stokes' paper. The case considered was that of a solid of revolution, the equation of whose meridian section could be thrown into a particular form.[4] The fact that in every body there are three directions which possess the same property was explicitly stated and proved by Kirchhoff in his paper referred to below.

The starting point for the investigation of the motion here considered was given by the publication in 1867 of Thomson and Tait's 'Natural Philosophy.' Here the authors applied the Lagrangian equations of motion of a dynamical system directly to the energy of the fluid, expressed as a quadratic function of the component velocities of the body, which, referred to axes fixed in the body, has constant coefficients. By this means the general properties of the motion of a solid of revolution in a fluid, and moving in one plane, are deduced with the greatest ease. In the general case there are twenty-one constant coefficients which may be supposed known, and may either be found by analysis (theoretically at least) or by experiment (just as coefficients of self- and mutual induction in the case of electric currents) by finding the impulses necessary to generate the unit velocities and their combinations two-and-two. The general theory of the impulse as applied to fluid motion has been very fully developed by Sir W. Thomson[5] in his paper on vortex motion, before referred to.

We have already seen (p. 4) how he has shown that when the motion can be produced from rest by application of forces to the solids

[1] 'The thermodynamic theory of waves,' *Trans. Roy. Soc.* 1870.

[2] 'On some cases of Fluid Motion,' *Trans. Camb. Phil. Soc.*, viii. p. 105; also in Reprint of Papers, p. 50. For a proof of this from the theory of stream lines and many illustrations of other points in fluid motion, see Froude in *Nature*, xiii.

[3] 'Vom Widerstande der Flüssigkeiten gegen die Bewegung fester Körper,' *Pogg. Ann.*, 93 (1854); also 'Determination of the motion of conoidal bodies through an incompressible fluid,' *Quart. Jour. Math.*, i. p. 301.

[4] See under special problems.

[5] *Trans. R.S.E.*, xxv.

alone, Lagrange's equations are applicable directly to the expression for the energy. Now in this, the coefficients are, in general, functions of the angular co-ordinates of the body referred to fixed axes. If the energy be expressed in terms of the velocities referred to axes fixed in the body, the expression has constant coefficients. It is therefore advantageous to determine the form of the equations of motion when the energy is so expressed. This had been effected by him in 1858,[1] but was not published until 1871.[2] At the same time also, the form of the equation for the motion of a single solid, with any number of apertures in it and cyclic motion through them, a case in which the conditions of direct applicability of Lagrange's equations are not satisfied, were deduced. When there are several solids, of which some at least have apertures, the equations are naturally more complicated. The equations of motion for this case were published[3] by the same author in March, 1872; they have also been proved in a different manner in the new edition of Thomson and Tait's 'Natural Philosophy,' and have been already referred to.

I adduce here some of the chief results of the above analysis as developed by Sir W. Thomson. In the 'Natural Philosophy' was considered the case of the motion of a solid of revolution in an infinite fluid so as always to keep its axis in one plane. A certain fixed point in the axis (the centre of reaction) determinate when the form and distribution of mass in the body is known, moves in a sinuous line cutting the line of resultant impulse at equal intervals, and the body swings about the centre of reaction according to the law of the quadrantal pendulum. If A, B are the impulses necessary to produce unit velocity along and perpendicular to the axis, and μ the impulsive couple to produce unit rotation, then the length of the simple pendulum keeping time with the swinging of the body is $g\mu AB/\xi^2(A - B)$, ξ being the resultant impulsive *force* of the motion. This is on the supposition that there is no perforation with cyclic motion through it. An example of this latter was solved in the same manner for a circular tore with no rotation round its axis, in the paper 'On the motion of free solids through a liquid.' Here, when the ring is projected with a rotation round a diameter, its axis oscillates rotationally according to the law of a horizontal magnetic needle carrying a bar of soft iron rigidly attached to it parallel to the magnetic axis. In the same paper Thomson has also treated the question of the general motion of a solid of 'complete isotropy with helicoidal quality.'[4] The point P about which the body is isotropic moves uniformly in a circle or spiral so as to keep at a constant distance from the axis of the impulse, and the components of angular velocity round any three rectangular axes are constant.

In the 'vortex motion' he has shown, from general reasoning, that if a solid moves from a great distance past a fixed obstacle to a great

[1] Referred to by Rankine (1863) 'On plane water lines in two dimensions,' *Trans. Roy. Soc.* (1864). Reprint of Rankine's Papers, p. 495.

[2] 'On the motion of free solids through a liquid,' *Proc. R.S. Edinburgh*, vii. p. 384. See also p. 60.

[3] 'On the motion of rigid solids in a liquid circulating irrotationally through perforations in them or in any fixed solid,' *Ibid.* p. 668.

[4] The following is Thomson's example of such an isotropic helicoid: 'Take a uniform sphere and place on it projecting vanes in the proper positions—*e.g.*, cutting at 45° each at the middles of the twelve quadrants of any three mutually perpendicular great circles.' Of course the vanes in practice must not have sharp angles, else discontinuous motions will mask the effects.

distance on the other side it will have its path turned towards or from the fixed obstacle according as the direction of the impulse is in the same direction as, or the opposite to, that of translation. This follows at once after it is proved that the effect of the fixed obstacle is to add an impulsive component towards itself. In the paper which treats of polycyclic motion with several solids is given an example of a sphere moving in a fluid in which there are infinitely fine immovable curves round which polycyclic motion exists. Here the sphere moves as a material particle, whose mass is equal to the mass of the sphere and half the fluid displaced, under the action of the impressed forces, and in a field of force whose potential is W, where W is the work done in moving the sphere to an infinite distance from the cores of the polycylic motions; *or* the difference of the fluid energies in the cases when the sphere is not present, and when it is. When the core is an infinite straight line, the paths of globules arbitrarily projected are Cotes's spirals.

I have thought it well to refer to those papers of Thomson's together, as they form a connected series, although between their publications important essays have appeared from other investigators. The first of these requiring mention is Kirchhoff, who taking up the question of the general motion of a body of revolution as treated in Thomson and Tait applied the same methods to extend their results when the motion is not confined to one plane. His investigation[1] was published in March, 1870. He deduced by analysis alone the Eulerian[2] form of the equations of motion in the same form as Thomson's. Taking the origin at the centre of reaction he obtains equations for the velocities and the co-ordinates which enable them to be expressed as elliptic functions of the time. Considering more closely the case already solved in Thomson and Tait's treatise, he finds explicitly the velocities in terms of the time, and expresses the constants in terms of the constants of the kinetic energy and the initial motion. Two cases present themselves which depend on the energy-constants, and each of these subdivides into two subcases according to the initial motion. These may be expressed thus. If it requires a less impulse to produce unit velocity *along* the axis than *perpendicular* to it, then the velocity along the former is expressible by means of the *sn* functions and *vice versâ.* Calling the larger and smaller impulses A, B respectively, each case divides into two subcases, according as the ratio of the energy due to rotation bears to the energy due to the other velocity a greater or less ratio than $(A - B)/B$ which corresponds to the case of the rotation and velocity being expressed by *dn*, *cn* respectively, or *vice versâ.* Kirchhoff finds also that it is possible to project a solid of revolution with rotation round a line perpendicular to its axis, so as to describe a circular helix—a result, which by Thomson's theory of the impulse, is at once seen to be true. In the same volume Kirchhoff[3] considered the forces between any two infinitely thin rings with circular section through which cyclic motion is taking place, and proved that the apparent forces between them are equal to those which would exist between them if they were conductors and electric currents flowed along them. The same

[1] 'Ueber die Bewegung eines Rotationskörpers in einer Flüssigkeit,' *Borch.*, lxxi. p. 237.

[2] Thomson has proposed to keep the term 'Eulerian' for equations of motion referred to axes fixed in the moving body.

[3] 'Ueber die Kräfte, welche zwei unendlich dünne starre Ringe in einer Flüssigkeit scheinbar auf einander ausüben können,' *Borch.*, lxxi. p. 263.

question was taken up by Boltzmann[1] later, who has considered the case of non-circular section. He notices that Kirchhoff's analogy is not exact, as the forces due to the motion of the rings vanish in the case of fluid motion.

Kirchhoff's investigation of the solid of revolution was completed in 1877 by Köpcke,[2] who did for the general case of a solid of revolution what Kirchhoff had done for Thomson and Tait's solution. He succeeded in expressing the elements of the motion and the position at any moment by means of the elliptic and Θ functions, using a quadric transformation to reduce the functions in u, the velocity along the axis, to the canonical form. In this also two chief cases occur distinguished as in the simpler case mentioned above. The same end was also attained by a somewhat different process by Greenhill.[3]

In the case of any solid whatever, we obtain at once three integrals in the form of constant energy, constant impulsive force, and constant impulsive couple. Clebsch noticed that if a fourth integral could be obtained, a fifth could be at once deduced by the principle of the last multiplier; and the last integral, giving the value of t, be then found by quadratures. In the 'Mathematische Annalen'[4] for 1871, soon after Kirchhoff's paper, he set himself the problem to discover when the equations admitted (α) of a linear integral, (β) of a quadric integral not compounded of the first three integrals. Instead of the velocities, he takes the momenta for dependent variables. Writing x_1, x_2, x_3, for the component impulsive forces of the motion and y_1, y_2, y_3, for the component impulsive couples, the energy can be expressed in the form $T_1 + T_2 + T_3$ where T_1, T_3 are quadric functions of the (x) and (y) respectively, and T_2 contains only products of an x into a y, which he proves may by a proper choice of the origin be such that the coefficients of $x_i y_j$ and $x_j y_i$ are the same. For a linear integral the condition found is that T must be expressible in the form[5]—

$$a(x_1^2 + x_2^2) + a_1 x_3^2 + b\ (x_1 y_1 + x_2\ y_2) + \beta x_3 y_3 + c(y_1^2 + y_2^2) \\ + c_1 y_3^2$$

when $y_3 = \text{const.}$ is an integral. This includes Kirchhoff's case and Thomson's isotropic helicoid. For a quadric integral three cases appear, one of which reduces to the square of the above; the other two are that T must be expressible in either of the forms

$$T_1 + \lambda\ (x_1 y_1 + x_2\ y_2 + x_3 y_3) + \mu\ (y_1^2 + y_2^2 + y_3^2) \qquad (\alpha)$$

$$\text{or} \quad a_1 x_1^2 + a_2 x_2^2 + a_3 x_3^2 + b_1 y_1^2 + b_2 y_2^2 + b_3 y_3^2 + \lambda\ (x_1 y_1 \\ + x_2 y_2 + x_3 y_3). \qquad (\beta)$$

$$\text{where} \qquad \frac{a_2 - a_3}{b_1} + \frac{a_3 - a_1}{b_2} + \frac{a_1 - a_2}{b_3} = 0$$

when the integrals are respectively

$$\text{for } (\alpha) \qquad \lambda T_1(y) - \Delta = \text{const.}$$

[1] 'Ueber die Druckkräfte, welche auf Ringe wirksam sind, die in bewegte Flüssigkeit tauchen,' *Borch.*, lxxiii. p. 111.

[2] 'Zur Discussion der Bewegung eines Rotationskörpers in einer Flüssigkeit,' *Math. Annalen.*, xii. p. 387.

[3] 'Motion of an ellipsoid in liquid,' *Quart. Jour. Math.*, xvi. p. 242.

[4] 'Ueber die Bewegung eines Körpers in einer Flüssigkeit,' *Math. Ann.*, iii. p. 238.

[5] In other words, the solid must be similar to itself turned through one right angle.

where Δ is a quadric function of the (x) whose coefficients $(A_{i\kappa})$ are the minors of the determinant formed by the coefficients $(a_{i\kappa})$ of T_1 (discriminant of T_1) and for (β)

$$\frac{a_2 - a_3}{b_2 - b_3}x_1^2 + \frac{a_3 - a_1}{b_3 - b_1}x_2^2 + \frac{a_1 - a_2}{b_1 - b_2}x_3^2 + (y_1^2 + y_2^2 + y_3^2) = \text{const.}$$

The case where the last condition is satisfied has been investigated by Weber[1] when the impulse of the motion reduces to a single force—in other words, when the state of motion can be produced by a single blow applied to a point rigidly connected with the body. Out of the sixteen Theta functions of the first order of two variables, it is possible, in several ways, to choose nine, whose ratios to a tenth, multiplied by proper constants, are suitable to express the direction cosines of one set of rectangular axes to another. Weber shows that, taking the two variables to be linear functions of the time $a\,t + \beta$, $a_1\,t + \beta_1$, and those nine ratios to represent the direction cosines of the axes fixed in the body, to the axes fixed in the space, it is possible, if Clebsch's last condition above is satisfied, to determine the constants, so that three other ratios may represent the rotations about the set of axes fixed in the body, and the remaining three the rotations about the axes fixed in space, provided the motion is such that there is no impulsive couple. There remain four constants to be determined by the initial conditions, viz., two relations between three moduli of the Theta functions and the two constants β β_1. Four cases occur as in the previous investigations, which depend on the initial state. These are distinguished in the latter part of the paper. He also treats the equations in another way by direct integration by means of hyper-elliptic integrals.

The motions of a solid about a fixed point in fluid under the action of no forces, and about a fixed axis under the action of gravity, have been investigated by Michaelis.[2]

In a remarkably suggestive paper in the 'Proceedings of the London Mathematical Society,'[3] Lamb has applied Ball's theory of screws to the question of the steady motion of any solid in a fluid. It is easy to see that there are a simply-infinite system of steady motions, each being a screw motion, whose axis lies on a certain skew surface. The axis of each screw must coincide with the axis of the generating wrench, but their pitches are not necessarily the same. If the ratio of the impulsive force to the rotation set up is given, there are three screws of steady motion perpendicular to each other, though not necessarily intersecting. Amongst the infinite system of permanent screws, it is possible to choose sets of six mutually conjugate screws amongst which there is one set which contains three of infinite pitch (which correspond to the three steady translations), and three others which are such that the necessary generating wrenches have zero pitch, *i.e.* reduce to impulsive couples. This latter set of three is important, as by its means it is possible to construct the motion when the generating wrench reduces to any couple whatever. The following is Lamb's method of representing the motion. The three

[1] 'Anwendung der Thetafunctionen zweier Veränderlicher auf die Theorie der Bewegung eines festen Körpers in einer Flüssigkeit,' *Math. Annalen*, xiv. p. 173.

[2] 'Mouvement d'un solide dans un liquide,' *Archives Néerlandaises des Sciences exactes et naturelles*, Harlem, viii.

[3] 'On the motion of a solid through an infinite mass of liquid,' *Proc. Lond. Math. Soc.*, viii. p. 273 (1877).

sets of screws just mentioned do not in general intersect, but their axes lie along the alternate edges of a parallelopiped. Take the centre of this parallelopiped, and call it O. Then the motion of the body is compounded of the motion of O, and a motion about O. Describe about O, as centre, a certain ellipsoid, which, as in Poinsot's representation, gives the motion relative to O by rolling on a plane with angular velocity proportional to the instantaneous axis OI. The motion of O is then represented by drawing round O another determinate quadric. Suppose OI cuts the quadric in P, and OM is the perpendicular from O on the tangent plane at P; then the motion is completely represented by supposing the Poinsot ellipsoid and plane to move bodily in the direction of OM with a velocity proportional to OI / (OP. OM). For particular forms of the body this naturally simplifies very much; for instance, in the case of an isotropic helicoid, any screw through O is a permanent one. The motion is stable about two of these fundamental screws and unstable about the third. Some of Lamb's results have since been obtained by Craig.[1] The steady motion of a solid of revolution has also been treated by Greenhill,[2] who has given an expression for the least rotation about the axis of a prolate solid of revolution that it may keep its point in front. An investigation similar to Greenhill's was given by Craig[3] about the same time.

The general theory of the motion of more than one body in a fluid has not hitherto received much attention. Many special problems have been solved, especially the case of two or more spheres by several writers. But these, beyond those referred to above, will best be noticed later under special problems. Most of the qualitative results obtained for spheres, no doubt hold good for solids in general. We may then expect that bodies vibrating in a fluid will appear to act on one another with forces varying according to inverse powers of the distance higher than the second, while pulsating bodies (or bodies changing their volume periodically) will have the chief part of their action proportional to the inverse square of the distance.

(e) *Viscous Fluids.*

The general theory of viscous fluids presents difficulties which can scarcely even yet be said to be settled. The equations of motion have not the same degree of certainty as in the case of perfect fluids, partly on account of the difficulty of finding a satisfactory theory on which friction is to be explained, and partly on the difficulty, as Stokes has pointed out, of connecting the oblique pressures on a small area with the differentials of the velocities. In the last report to the Association Professor Stokes has given a clear description of the various methods by which, up to 1846, Navier, Poisson, St. Venant, and he himself had attacked the problem. Since then several others have investigated the subject with results most of which can be expressed in (what may be called) the typical form—

$$\rho X - \frac{dp}{dx} = \rho \frac{Du}{Dt} - A \nabla^2 u - B\frac{d\theta}{dx}$$

where θ denotes the cubical compression. In Stokes' form, which is that

[1] 'The motion of a solid in a fluid,' *Amer Jour. Math.*, ii. p. 167.

[2] 'Motion of an ellipsoid in fluid,' *Quart. Jour. Math.*, xvi. p. 255, and xvii. p. 86; also for numerical applications to gunnery, see papers by the same author in the *Proc. Royal Artillery Inst.* x. xi.; and art. 'Hydrodynamics,' *Encyc. Brit.*, 9th edit.

[3] 'On the motion of an ellipsoid in fluid,' *Amer. Jour. Math.* ii. p. 271.

generally received, $A = 3B$. O. E. Meyer [1] (1861) assumes that the friction on a small plane in a given direction in the plane is proportional to the rate of variation perpendicular to the plane of the component of velocity in the given direction, whilst there is a normal part, proportional to the rate of variation perpendicular to the plane, of the component perpendicular to the plane. This is not so stated in his preliminary hypothesis, but is what his initial expressions imply. Considering then a small parallelopiped $dx\, dy\, dz$, he arrives at the above form of equation if B is put zero, which agrees with the results found by previous investigators for incompressible fluids only. Stefan [2] (1862) applies directly the methods of elasticity to a small tetrahedron treating the forces as functions of the nine differential coefficients of $u\ v\ w$, and shows, as in the theory of elastic solids, that the forces are of the form—

$$\chi_x = \lambda\theta + 2\mu\frac{du}{dx}, \text{ \&c.} \qquad \chi_y = \mu\left(\frac{du}{dy} + \frac{dv}{dx}\right), \text{ \&c.}$$

He now attempts to find a relation between λ and μ on the following hypothesis. Drawing a small plane through the direction of the velocity at any point, then the friction must fall in this plane and be parallel to the direction of the velocity. From this it results that $\lambda = o$. Stokes' corresponding assumption was that a uniform expansion of any element does not require a re-arrangement of the molecules, which leads to $\lambda = -2\mu/3$. Stefan's equations then give, in the typical form, $B = o$. From a totally different point of view has Maxwell [3] approached the subject when the fluid in question is gaseous. He bases his theory of viscosity on the transference of momentum from one layer to another by the moving particles of a gas, treating a gas according to the kinetic theory. He obtains precisely the same expressions as Stokes. But this investigation of Maxwell's is far more important from another point of view, in that he attempts to express the unknown constant of internal friction in terms of known properties of the medium. The first attempt towards this was made in his first paper [4] on the kinetic theory of gases (1860), where on the same bases as to the cause of friction he calculates the constant on the supposition that the atoms of a gas are spherical and perfectly elastic, with the result that the constant is proportional to the square root of the absolute temperature and is independent of the density. O. E. Meyer [5] (1865) also arrived at similar results from the same data. But this does not agree with experience, and Maxwell returns to the question again in the paper already mentioned. The fact that the coefficient of viscosity is independent of the density follows, whatever be the law of repulsion between the particles, but the law of its variation with the temperature depends on the law of force. Maxwell has chosen the inverse fifth, from which it results that the coefficient is directly proportional to the absolute temperature. Maxwell's result in this case is that $A = kp/\rho$ where k is a constant depending only on the mass of a molecule and the force between two molecules at unit distance. He has also given an expression for the

[1] 'Ueber die Reibung der Flüssigkeiten,' *Borch*, lix. p. 229. He acknowledges in 1874 (*Borch.* lxxviii. p. 131) that the investigation is not general.

[2] 'Ueber die Bewegung flüssiger Körper,' *Sitz. Akad. Wiss. Wien*, xlvi. p. 8.

[3] 'On the dynamical theory of gases,' *Trans. Roy. Soc.*, 1867, p. 81.

[4] 'Illustrations of the dynamical theory of gases,' *Phil. Mag.*, 1860, January and July.

[5] 'Ueber die innere Reibung der Gase,' *Pogg. Ann.* cxxv.

coefficient in a mixture of gases. Later experiments [1] have shown that the proportionality of the viscosity to absolute temperature does not hold for all gases. But Maxwell's work shows in any case that the connection between them depends on the law of force, which is certainly a complicated one, and not likely *à priori* to be the inverse fifth. Possibly for an attractive force the viscosity might decrease with increase of temperature, and if so would form an answer to Stefan's objection against making the same explanation of friction a basis for a theory of the viscosity of liquids. Lamb, in his treatise on hydrodynamics, deduces the equation by a method based on those of Stokes and St. Venant. Boussinesq [2] applies the equations for an elastic solid directly.

M. Levy [3] attempts to show that the stress cannot be represented by functions of the form:—

$$X_x = \Sigma C_n \left(\frac{du}{dx}\right)^n, \text{ \&c.} \qquad X_y = \Sigma C_n \left(\frac{dv}{dx} + \frac{du}{dy}\right)^n, \text{ \&c.}$$

but that the exact expressions are of the form—

$$X_x = p + 2e_0 \frac{du}{dx} + 2\Sigma e_n \nabla^{2n}\left(\frac{du}{dx}\right), \text{ \&c.}$$

$$X_y = (e_0 + \Sigma e_n \nabla^{2n}) \left(\frac{dv}{dx} + \frac{du}{dy}\right), \text{ \&c.}$$

whilst M. Kleitz,[4] arriving at the same result as to the error of the ordinary method of expressing the stresses, starts by supposing the constants to vary for different small planes round a point, and tries to find the law of this variation. Meyer [5] has also deduced equations of motion on the supposition that the action between two particles takes time to act.

In the 'Proceedings' of the London Mathematical Society, Butcher [6] has attempted to develop a general theory which would comprise the theory of elastic solids and perfect fluids as particular cases. He supposes a body composed of small groups of molecules differing from one another, which he divides into two classes: (A) which recover their original form after being subjected to a strain less than a certain amount, and (B) those in which this limiting strain is zero. When only A groups are present we have an elastic solid; when A and B groups are present the body partially returns to its original configuration after a strain, but the amount of its return is a function of the previous duration of the strain; if the body does not return at all, B groups only are present, and we get a viscous or perfect fluid according as the acting stress is finite or infinitesimally small. With varying proportions of A and B groups appear different

[1] For a discussion of this point the reader is referred to O. E. Meyer's *Die Kinetische Theorie der Gase.* Breslau, 1877, p. 157. Also for a full abstract of what is known experimentally on the subject.

[2] 'Mémoire sur l'influence des frottements dans les mouvements réguliers des fluides.' *Liouville* (2) xiii. p. 377.

[3] 'Rapport sur un Mémoire de M. Maurice Lévy relatif à l'hydrodynamique des liquides homogènes, particulièrement à leur écoulement rectiligne et permanente.' *Comptes Rendus*, lxviii. p. 582.

[4] 'Rapport sur un Mémoire de M. Kleitz, intitulé études sur les forces moléculaires dans les liquides en mouvement, et application à l'hydrodynamique.' *Comptes Rendus*, lxxiv. p. 426.

[5] 'Zur Theorie der inneren Reibung,' *Borch.* lxxviii. p. 130. Zusatz zu der Abhandlung 'Zur Theorie der inneren Reibung,' *Borch.* lxxx. p. 315.

[6] 'On viscous fluids in motion,' *Proc. Lond. Math. Soc.*, viii. p. 103.

proportions of elasticity, plasticity, and viscosity. For viscous fluids, or where B groups only are present, the equations of motion are found on the supposition that in any element the groups not thrown out behave as elastic solids, whilst those thrown out behave as perfect fluids, *i.e.* are only in a state of contraction or dilatation, and that a strain of the element is the sum of the strains of the first as an elastic solid, and of the second as dilatations. The final equations obtained are:—

$$\frac{1}{l+\frac{d}{dt}}\left\{\left(kl+(k+\tfrac{1}{3}\nu)\frac{d}{dt}\right)\frac{d\theta}{dx}-\nu\nabla^2 u\right\}+\rho\left(X-\frac{Du}{Dt}\right)=0,$$

with two others, where l is the ratio of the number of groups thrown out per unit of time to those not thrown out, and ν, k are the rigidity and resistance to dilatation respectively for the elastic groups. With l large or viscosity small, this becomes—

$$k\frac{d\theta}{dx}-\frac{\nu}{l}\nabla^2 u+\rho\left(X-\frac{Du}{Dt}\right)=0,$$

whilst for l small (as in Canada Balsam), it is—

$$(k+\tfrac{1}{3}\nu)\frac{d\theta}{dx}-n\nabla^2 u+\rho\left(X-\frac{Du}{Dt}\right)=0.$$

Mr. Butcher also forms the equations of motion for plastic solids on similar principles.

Bobylew [1] has transformed Stokes' form of the equations of motion of a viscous fluid to curvilinear co-ordinates, and has given expressions for the pressure at any point of a viscous fluid, and its rate of variation with the time, analogous to those given by Helmholtz for a perfect fluid. Simpler proofs of the same formulæ have been given since by Forsyth [2] and Craig.[3] When the motion at the boundary is zero, the rate of variation takes the simple form $-4\mu\iiint w^2 dxdydz$, where w is the rotation at the point $(x.y.z)$. It is clear, therefore, that with no motion at the boundary, or in an infinite fluid at rest at infinity, there must be dissipation of the energy of motion. Lipschitz [4] has also given expressions for the pressure within a viscous fluid under the action of external and internal attraction.

None of these theories can be regarded as perfectly satisfactory; even Stokes', which has been most generally accepted, introduces stresses, whose appearance, simply on the theory of friction acting on the surface of an element of fluid, it is difficult to understand. Take, for instance, the motion given by $u=ax$, $v=0$, $w=0$ in a compressible fluid; this gives a stress, *due to friction*, perpendicular to a small plane parallel to the plane of yz, where certainly no force can arise from friction, if we suppose it to act on the surfaces only. The method employed by Maxwell, and suggested by Stefan afterwards for extension to liquids, would seem the more hopeful road, but we must wait until the motions of the molecules of liquids are better understood than at present. On a

[1] 'Einige Betrachtungen über die Gleichungen der Hydrodynamik,' *Math. Ann.* vi. p. 72.

[2] 'On the motion of a viscous incompressible fluid,' *Mess. Math.* ix. p. 134.

[3] *Journal of the Frankland Institute*, October, 1880. Also 'On certain possible cases of steady motion in a viscous fluid,' *Amer. Jour.*, iii. p. 269.

[4] 'Determinazione della pressione nell' interno d'un fluido incompressibile soggetto ad attrazioni interne ed esterne,' *Brioschi, Ann.* (2) vi.

theory of this kind it is easy to see that forces will exist whose appearance on any theory of surface-friction in the equations of stress is here objected to. There can, however, be little doubt that for small motions at least the ordinary equations give trustworthy results. Maxwell, in a note published at the end of a paper by Rohrs[1] has pointed out a way to obtain limits of error in some particular cases by the consideration of error-forces.

The question of steady motion in viscous fluids has been considered by Craig,[2] who has proved that if everywhere $\nabla^2\xi$, $\nabla^2\eta$, $\nabla^2\zeta$ (ζ, η, ζ, being components of rotation) be zero, or in other words if $\nabla^2 u\, dx + \nabla^2 v\, dy + \nabla^2 w\, dz$ be a perfect differential, the motion is steady. In this paper several interesting transformations of the equations of motion, and of the dissipation function are given. Oberbeck[3] had before this shown that when the motion is very small and steady, the vanishing of $\nabla^2\xi$, $\nabla^2\eta$, $\nabla^2\zeta$ is a necessary consequence.

Helmholtz[4] has given a method by which in certain cases the motions of one fluid with given conditions can be directly deduced from that of another fluid whose motion is geometrically similar. Denoting by $u\ v\ w$ the velocities at time t, at the point $(x.y.z)$ of a fluid whose density is ρ, pressure p, and coefficient of viscosity μ, and using dashed letters to denote the same quantities for another fluid, he points out that when there are no external forces the equations of motion are also satisfied by $\mu_1 = q\mu$, $\rho_1 = r\,\rho$, $u_1 = nu$, &c., $x_1 = qx/n$, &c., $p_1 = n^2rp +$ const., $t_1 = qt/n^2$ where $q.\ r.\ n$ are three constants, two of which, $q.\ r$, are determined by the nature of the fluids, the other, n, is arbitrary for an incompressible fluid, but for a compressible fluid n must be the ratio of the velocity of sound in the second fluid to that in the first. In incompressible viscous fluids, in which bodies are immersed, n will be determined by the ratios of the coefficients of slipping at their surfaces. If this coefficient is zero, or if there is no viscosity, we may take into consideration the action of gravity, but then $n^3 = q$. The resistances to the motion of similar bodies in the fluids are in the ratio $q^2r : 1$, whilst the rates of work done in overcoming these resistances are as $nq^2r : 1$. Many interesting results flow at once from the foregoing considerations, *e.g.*, the fact that in waves on the surface of a heavy incompressible fluid, the velocity of propagation of similar waves in similar vessels is always, whatever their form, proportional to the square root of the wave-length; this follows at once by putting $q = n^3$ whence $x_1 = n^2x$, $t_1 = nt$. Helmholtz applies these considerations to the relations between ships and their horse-power, birds and their muscular power, and works out with numerical details the relations between ships and similarly shaped balloons, with reference to volume, horse-power, and tonnage. For these results the reader is referred to the paper itself.

[1] 'Spherical and Cylindrical Motion in Viscous Fluid,' *Proc. L. Math. Soc.* v. p. 125.

[2] 'Viscous Fluids,' *Jour. Frankland Inst.*, Oct. 1880, p. 217. 'On certain possible cases of steady motion in a viscous fluid,' *Amer. Jour. Math.* iii. p. 269. A similar statement is also given by Graetz (*Zeits. f. Math. u. Phys.* xxiv. p. 239: 'Einige Sätze über Wirbelbewegungen in reibenden Flüssigkeiten'), but with an evident error as to non-possibility of production of vortices in such a motion by conservative forces.

[3] 'Ueber stationäre Flüssigkeitsbewegungen mit Berücksichtigung der inneren Reibung,' *Borch.* lxxxi. p. 62.

[4] 'Ueber ein Theorem, geometrisch ähnliche Bewegungen flüssiger Körper betreffend, nebst Anwendung auf das Problem, Luftballons zu lenken,' *Monatsber. Berl.* (1873) p. 501.

The principle may be compared with that of Newton's principle of dynamical similitude. An example illustrating Helmholtz' results is given by Rayleigh[1] on the analogy between the two dimensional vibrations of air in a cylindrical tube of any section, and the liquid waves contained in a vertical cylindrical vessel of the same section.

f. Waves in Liquids.

The subject of waves was one which received much attention amongst English mathematicians about the period between 1840 and 1850, and the labours of Green, Kelland, Earnshaw, and Airy have been noticed by Professor Stokes in the last report to the Association. Almost immediately after this report he himself read a paper before the Cambridge Philosophical Society 'On the Theory of Oscillatory Waves,'[2] in which was investigated the form and properties of waves which are propagated *without change of form* and irrotationally. It appeared that with these conditions[3] given, to a given velocity of propagation corresponded one definite form; when the height is small compared with the wave-length, the wave-form is the curve of sines; but if the height is comparable with the wave-length this is not the case, but the crests of the waves are steeper than the hollows, and this difference becomes more prominent the shallower the fluid is. A curious result of the analysis is that the fluid particles, in addition to a motion of oscillation have also a small one of translation, which depends on the square of the ratio of the height to wave-length, a result which Rayleigh[4] has shown to depend directly on the absence of molecular rotation of the wave. In this paper Stokes carried the approximation to a second order for finite depths, and to a third order when the depth of fluid is infinite. In the reprint of his papers[5] (1880) he adds a supplement to the above in which a totally different method is employed. Instead of taking the rectangular co-ordinates of a particle as independent variables and expressing the velocity potential thereby as usual, the velocity potential and stream functions are taken as independents and the co-ordinates of a point sought in terms of them. This so much simplifies the calculation that it is an easy matter to press the approximation to the fifth order for infinitely deep fluids, and to the third order for those of finite depth. In infinitely deep fluids a wave-form of length $2\pi/m$ and height $2a+\frac{3}{4}m^2a^3$ the velocity of propagation (c) is given by[6]

$$c^2 = \frac{g}{m}\left(1 + m^2a^2 + \tfrac{5}{4}m^4a^4\right)$$

[1] 'On Waves,' *Phil. Mag.* (5) i. p. 275.

[2] *Trans. Camb. Phil. Soc.* viii. p. 441. Also reprint, vol. i. p. 197.

[3] It will be seen below that another condition is implied, viz., the finiteness of wave-length.

[4] 'On Waves,' *Phil. Mag.* (5) i. p. 270.

[5] *Mathematical and Physical Papers.* G. G. Stokes. Vol. I. Cambridge University Press.

[6] If h = height of crest above the trough and λ = wave-length

$$c^2 = \frac{g\lambda}{2\pi}\left(1 + \frac{\pi^2h^2}{\lambda^2} + \frac{1}{2}\frac{\pi^4h^4}{\lambda^4}\right)$$

$$y + \frac{1}{4}\cdot\frac{\pi h^2}{\lambda^2}\left(1 + \frac{\pi^2h^2}{\lambda^2}\right) = \frac{1}{2}h\left(1 - \frac{3}{8}\frac{\pi^2h^2}{\lambda^2}\right)\cos\frac{2\pi x}{\lambda} - \frac{\pi h^2}{2\lambda}\left(\frac{1}{2} + \frac{1}{3}\frac{\pi^2h^2}{\lambda^2}\right)\cos\frac{4\pi x}{\lambda}$$

$$+ \frac{3}{16}\frac{\pi^2h^3}{\lambda^2}\cos\frac{6\pi x}{\lambda} - \frac{1}{6}\frac{\pi^3h^4}{\lambda^3}\cos\frac{8\pi x}{\lambda} + \ldots\ldots$$

and the form of the wave to the fourth order by

$$y + \tfrac{1}{2}ma^2 - \tfrac{1}{8}m^3a^4 = a \cos mx - \tfrac{1}{2}ma^2 (1 + \tfrac{17}{12} m^2a^2) \cos 2\,mx$$
$$+ \tfrac{3}{8} m^2a^3 \cos 3\,mx - \tfrac{1}{3} m^3a^4 \cos 4\,mx \ldots .$$

This embraces so far as the third order the results of the earlier paper. To the third order this agrees with the expansion for a trochoid, and therefore the curve approximates to Gerstner's and Rankine's form mentioned below.[1] In the same paper Stokes also considers the analogous problem for the waves at the common surface between two liquids. When the fluids are confined by horizontal rigid walls there is as before only one form of wave, for given velocity of propagation, and the velocity (c) is given by $2\pi c^2 = g\lambda\ (\rho - \rho^1)\ \{\rho\ \tanh\ 2\pi h/\lambda + \rho^1\ \tanh\ 2\pi h^1/\lambda\}^{-1}$ where h, h^1 are the thicknesses of the fluids, and the meanings of the other constants are evident. The case is different when the upper fluid has a free surface. Here either for given wave-length or for given velocity of propagation there are two possible systems of wave-forms. One of these, when the lower fluid is deep, corresponds to that form, which is propagated on a single surface, and this whatever the depth of the upper fluid. The other form is propagated with velocity given by $2\pi c^2 = g\lambda\ (\rho - \rho^1)\ (\rho\ \tanh\ 2\pi h^1/\lambda + \rho^1)^{-1}$.

Only one definite series of waves of permanent type can be propagated in a fluid in which no vortex motion is present; but it does not follow that this is the only permanent form which is possible in a perfect fluid. One other at least is known, which was first discovered by Gerstner[2] in 1802, and afterwards independently by Rankine[3] in 1862. The latter gives a most elegant geometrical proof that a trochoidal form of wave is a possible one, and that the velocity of propagation is $\sqrt{(g\lambda/2\pi)}$. Here the motion of any particle is a uniform one in a circle, the radius of the circle diminishing with the depth. In a later note[4] he discovers the essential difference between this mode of wave-motion and that considered by Stokes. It lies in the fact that the exact trochoidal waves possess molecular rotation. Stokes notices this in the reprint of his own papers[5] and points out that in order that such waves may be excited in a perfect fluid by operations on the surface alone a preparation must be laid in the shape of a horizontal velocity decreasing from the surface downwards according to the law $exp\,(-4\pi k/\lambda)$ where k is a function of the depth given by

$$\text{depth} = k - \frac{\pi a^2}{\lambda}\left\{1 - exp\left(-\frac{4\pi k}{\lambda}\right)\right\}$$

The physical interest therefore of these motions is not so great as has been sometimes thought.

The same objection, *amongst others*, lies against an attempt by Hagen[6]

[1] The theory of periodic waves has been treated by Boussinesq in a very long paper in the *Mém. par divers Savants*, xx. p. 509. He does not seem to have been acquainted with much of the work done outside France.

[2] 'Theorie der Wellen,' *Abhand. der Königl. Böhmischen Gesellschaft der Wiss.* 1802. Also printed separately, Prague, 1804. Also in Gilbert's *Annalen der Physik*, Bd. 32, p. 412.

[3] 'On the exact form of waves near the surface of deep water,' *Trans. Roy. Soc.*, 1863. Also Reprint, p. 481. St. Venant reproduces in the *C.R.*, lxxi. p. 186, a somewhat similar proof by M. Belanger, given by the latter in 1828.

[4] Reprint, p. 494.

[5] Appendix A to *Oscillatory Waves*, p. 219.

[6] 'Ueber Wellen auf Gewässern von gleichmässiger Tiefe.'—*Math. Abhand. könig. Akad. d. Wiss.* Berlin (1861), p. 1. This is a long drawn-out paper.

to develop a somewhat similar theory for a fluid of finite depth. In the trochoidal waves in deep fluids all the particles describe circles with uniform velocities. Hagen starts by assuming the path to be an ellipse distorted so that the higher and lower halves are raised from the symmetrical position, *i.e.* the paths are given by

$$x = a \sin \phi,\ y = \beta \cos \phi + \gamma \cos^2 \phi$$

where ϕ is a function of the time and α, β, γ are constants for each particle. He also assumes that particles in a vertical line always remain so. The condition of constant pressure at the surface as expressed by him is only approximately satisfied. St. Venant[1] has given for stationary waves a theory similar to that of Gerstner's for progressive waves, and has also attempted to develop a theory for progressive and stationary waves when the fluid is of a finite depth, but unfortunately his theory does not satisfy the equation of continuity.

The limiting form of trochoidal waves being the cuspidal, it is clear that permanent waves could exist whose crests would be infinitely fine, a result contradicted by experience if we suppose the theory actually to apply to waves as ordinarily seen, that is in irrotational motion. This alone would show that they cannot be taken as the type of naturally produced waves. In another wave-form considered by Rankine,[2]

$$\psi = 2\pi y/\lambda - exp\,(-2\pi y/\lambda) \cos 2\pi x/\lambda$$

the steepest form cuts itself at 90°; but this is a forced wave, that is the pressure along the surface is not constant. The velocity of propagation here also is $\sqrt{(g\lambda/2\pi)}$. In a supplement to this paper[3] he attempts to prove that all waves in which molecular rotation is null must begin to break when the two slopes of the crest meet at a right angle. But this has been criticised by Stokes[4] who has very neatly proved that if such a sharp angle is possible it must be one of 120°; and this is borne out by the fact that the analytical series for the permanent type of irrotational periodic waves seems to become divergent as the wave approaches the form with a crest of 120°.

The question of permanent types of waves of longitudinal disturbance through the medium, properly belongs to the domain of the theory of sound. It has been investigated by Stokes,[5] Earnshaw,[6] Riemann,[7] and Rankine.[8] The essential difference between this case and the preceding is that the medium must fulfil the condition $\rho^2 dp/d\rho =$ const. Earnshaw regarded this as unrealisable; but Rankine has shown that with a given law of conduction of heat, there are types of waves which can be pro-

[1] 'Sur la houle et le clapotis,' *Compt. Rend.*, lxxiii., p. 521, 589.

[2] 'Summary of the properties of certain stream-lines,' *Phil. Mag.* (4), xxviii. p. 282.

[3] *Phil. Mag.* (4), xxix., p. 25.

[4] *Math. and Phys. Papers.* App. B., 'Considerations relative to the greatest height of oscillatory irrotational waves which can be propagated without change of form,' p. 225.

[5] 'On a difficulty in the theory of sound,' *Phil. Mag.* (3), xxxiii. p. 349.

[6] 'On the mathematical theory of sound,' *Trans. Roy. Soc.* (1860), p. 133.

[7] 'Ueber die Fortpflanzung ebener Luftwellen,' Gött., *Abhand. Math. Class.*, viii. p. 43.

[8] 'On the thermodynamic theory of waves of finite longitudinal disturbance,' *Trans. Roy. Soc.*, 1870. Also Reprint, p. 530.

pagated so that this condition is satisfied. It is curious that sudden waves of condensation are permanent, whilst those of rarefaction are not so.

When the length of the wave is very great compared with the depth of the fluid, it is clear that the vertical motion of any particle is very small compared with the horizontal. A theory based on the neglect of the vertical motion is called a theory of long waves, and had been very fully treated by Lagrange, Airy, and others. If in addition to small ratio of depth to length, the ratio of height of wave to depth is also small, then to the first order of these quantities the wave is of a permanent type. But if the height of the wave has a finite ratio to depth of fluid Rayleigh [1] has shown that it is impossible for the waves to maintain their form. In order that it should do so the force of gravitation ought to vary as the inverse cube of the height above the bottom of the fluid. In the same paper he points out that in a canal of slowly varying section, if the velocity of the stream be less than that of a free wave, a contraction of the channel produces a decrease in wave-height, and *vice versâ.* The opposite happens if the velocity of the stream is greater than that of a free wave.

The theory of irrotational waves of permanent type, considered by Stokes, proceeds on the assumption that an infinite series of similar waves follow one another, or that the wave-length is finite; and we have seen how, in this case, the solution is unique for given velocity of propagation. But this theory does not take account of the question whether a solitary wave can be thus propagated; in fact, it is clear that the functions determining such a wave must not be expressible as a series of circular functions, as the motion is essentially non-periodic. That such waves exist has been known for a long period, since the experiments of Scott-Russell brought to light the wave called by him the *solitary* wave. In the last report, Stokes has mentioned Earnshaw's attempt at giving a mathematical theory of this kind of wave, and has pointed out the objection to it, that it requires a finite change of velocity and pressure at the beginning and end of the wave. Rayleigh has noticed that the cause of this is that Earnshaw's wave contains molecular rotation, whilst the fluid beyond the wave is at rest. A satisfactory theory has been given by Boussinesq,[2] when the curvature of the wave-profile is of such a magnitude that d^4y/dx^4 may be neglected. He deduces that the velocity of the wave is given by $\sqrt{gh}$ where h is the primitive depth of the fluid, which is Russell's result, as found by experiment. The form of the profile is given by $y = a \operatorname{sech}^2 x\sqrt{(3a/4\,h^3)}$, a being the height of the wave above the original surface. The centre of gravity of this wave is at one-third of its height above the undisturbed level. Boussinesq introduces a quantity, connected with any swelling of fluid propagated along the surface, which he calls the moment of instability. For all swellings of equal energy this momenti s least when the swelling is the *solitary* wave, which keeps its form; when the moment is not quite a minimum, the form of the swelling will oscillate about the permanent form given above. It follows, from the analysis, that a negative permanent wave is impossible, a result also of Russell's

[1] 'On Waves,' *Phil. Mag.* (5), i., p. 257 (1876).

[2] 'Théorie des ondes et des remous qui se propagent le long d'un canal rectangulaire horizontal, en communiquant au liquide contenu dans ce canal des vitesses sensiblement pareilles de la surface au fond,' *Liouville* (2), xvii. (1872), p. 55.

experiments. The paths[1] described in solitary waves by particles of the fluid are parabolic arcs with axes vertical, constant horizontal chord equal to the quotient of the volume of the wave by the primitive depth, and height proportional to the initial height of the particle above the bottom; being, for a particle at the surface, equal to the height of the wave. The latus rectum at the surface is four-thirds the primitive depth of the fluid, and varies for other particles inversely as their height above the bottom, and is independent of the height of the wave. Rayleigh[2] also gave, independently, a few years later, a theory of the solitary wave agreeing with that of Boussinesq's.

Rankine[3] has attempted to determine the velocity of propagation of any possible kind of wave in a liquid of limited or unlimited depth simply from the fact that the free surface is one of constant pressure. But, in reality, he implicitly assumes that the waves are of a permanent type. He proves that the velocity of propagation is equal to that acquired by a body in falling through half the *virtual depth.* In this, the velocity of the wave is defined as the mean of the velocities with which the form advances relatively to particles in the crest and trough respectively, and the virtual depth as follows: Suppose a stream flowing with a velocity equal to the difference of the velocities of the particles at the crest and trough; then the depth of stream, in order that the amount of horizontal disturbance should equal the whole amount of horizontal disturbance in the actual fluid between two vertical planes, through the crest and trough respectively, is the virtual depth. We have seen how an analogous theorem can be deduced from the theory of dynamical similarity.

In all the foregoing, the waves have been regarded as following each other in infinite series, or the whole extent of the fluid has been taken into consideration. The theory would have to be modified, therefore, when waves are propagated into fluid at rest. This happens, for instance, with the trail of waves from the bow of a boat, or the group of waves formed on the surface of water by periodically disturbing it for a short interval. It is then observed that the waves are not of the same size, but that they advance in a group, of which the largest are in the middle, and that the group itself progresses with only half the velocity of the waves themselves. If a single wave be observed, it is seen to die gradually out, while others are formed in its rear. The explanation of this was given by Osborne Reynolds, at the meeting of this Association at Plymouth, in 1877.[4] The energy of a liquid trochoidal wave is half kinetic and half potential, the latter of which is transmitted at the rate of its amount in unit of length × the velocity of the wave. It is then easy to see that, in a group of waves, which slightly decrease in size towards the front, the form of wave is transmitted twice as fast as the energy, and the velocity of the group is only one-half that of the waves composing it. The propagation of groups of waves had been considered before Reynolds, by Rayleigh,[5] who treated them as compounded of two infinite trains of waves, of equal amplitude and slightly different wave-length;

[1] 'Addition au Mémoire sur la Théorie,' &c. *Liou.* (2) xviii. p. 47.

[2] 'On Waves,' *Phil. Mag.* (5) i. p. 262.

[3] 'On Waves in Liquids,' *Proc. Roy. Soc.*, xvi. p. 344 (1868).

[4] The paper is published in *Nature*, xvi. p. 343: 'On the rate of progression of groups of waves, and the rate at which energy is transmitted by waves.'

[5] *Theory of Sound*, vol. i. p. 246.

and showed that if V is the velocity of propagation of a wave-form of length $2\pi/k$, the velocity of the group is $d(kV)/dk$. In the 'Proceedings of the Mathematical Society,'[1] Rayleigh extends Reynolds's theory to other types of waves, and attempts to show how his expressions for the velocity may result from the theory of the latter. If the velocity of the wave vary as the nth power of its wave-length, the velocity of group-propagation is $(1-n)$ times the velocity of the wave (V); thus, for deep-water waves it is $\frac{1}{2}$V; for aërial waves, V (beats travel with the same velocity as the notes); and for waves due to capillary action on the surface it is $\frac{3}{2}$V.

The theory of these latter waves has been given by Thomson.[2] The velocity of propagation with air of density σ, above water whose superficial tension is T is $\sqrt{(g_1\lambda/2\pi + 2\pi T_1/\lambda)}$ where $g_1 = g(1-\sigma)/1+\sigma)$ and $T_1 = T/(1+\sigma)$. So long as the wave-length is less than $2\pi\sqrt{(T_1/g_1)}$ the velocity of propagation increases as the wave-length diminishes, and the capillary tension has most effect in producing the motion, while if the wave-length is greater, the velocity of propagation increases with the wave-length, and gravity has most effect. Thomson proposes to confine the name *ripples* to fluid waves whose wave-length is less than this critical value. The velocity of propagation is then a minimum and $\sqrt{(2\sqrt{(g_1T_1)})}$. For water, this gives a velocity of 23 centimeters per second for a wave-length of 1·7 centimeters. This result agrees well with some experiments made by him on sea water. When wind acts on the surface, the results are modified, the wave-velocity with a wind-velocity equal to V is equal to $\sigma V/(1+\sigma) \pm \{w^2 - \sigma V^2(1+\sigma)^{-2}\}^{\frac{1}{2}}$ where w is the velocity, without wind. The discussion of this formula leads to interesting results; for instance, that the surface of still water is unstable if the velocity of the wind exceeds

$$\sqrt{\left(2\sqrt{\left(gT\frac{1-\sigma^2}{\sigma}\right)}\right)},$$

This accounts for the fact that a *small* breath of wind sweeping over the surface of still water dims the surface only while it lasts, for the capillary waves die away at once through the viscosity of the water. The values of the velocity of propagation of capillary waves on water without air, have been found by Kolácek,[3] apparently without knowledge of Thomson's work.

Some very elegant illustrations of Huyghen's principle as applied to liquid waves have been given by Hirst.[4] He has developed the differential equations for the line of ripple due to any centres, or lines of disturbance, which give small waves, as, for instance, the ripples just mentioned, on the surface of fluid moving in any manner; and has applied them particularly to the case where the centre of disturbance describes a circle uniformly on still water. The results are compared with experiment, with full agreement between theory and practice.

The theories of straight waves in a vertical square cylinder, and of

[1] 'On progressive waves,' *Proc. Lond. Math. Soc.*, ix. p. 21. He states that the theory is originally due to Stokes.

[2] 'Hydrokinetic Solutions,' parts 3, 4, 5, *Phil. Mag.* (4) xlii. p. 368.

[3] 'Ueber den Einfluss des capillaren Oberflächendruckes auf die Fortpflanzungsgeschwindigkeit von Wasserwellen,' Wied. *Ann.* v. p. 425.

[4] 'On Ripples and their relation to the velocities of currents,' *Phil. Mag.* (4), xxi. p. 1 and 188.

cylindrical waves in circular vessels, have been investigated by Rayleigh[1] and compared with his own experiments and those of Professor Guthrie[2] published in 1875. The question has also been investigated by Giesen.[3] Kirchhoff[4] has considered plane waves in a rectangular trough whose sides are equally inclined to the vertical, the crests of the waves being parallel to the sides.

Report of the Committee, consisting of Sir WILLIAM THOMSON, Professor ROSCOE, Dr. J. H. GLADSTONE, *and* Dr. SCHUSTER (*Secretary*), *appointed for the purpose of collecting information with regard to Meteoric Dust, and to consider the question of undertaking regular observations in various localities.*

THIS Committee was appointed for the double purpose of examining the observations hitherto recorded on the subject of meteoric dust, and of discussing the possibility of future more systematic investigations.

With regard to the first point, we note that in a paper presented to the Royal Astronomical Society [5] in 1879, Mr. Ranyard has given what appears to be a pretty complete account of the known observations as to the presence of meteoric dust in the atmosphere.

It appears that in the year 1852 Professor Andrews found native iron in the basalt of the Giant's Causeway. Nordenskjold found particles of iron, which in all probability had a cosmic origin, in the snows of Finland and the icefields of the Arctic regions. Dr. T. L. Phipson, and, more recently, Tissandier, found similar particles deposited by the winds on plates exposed in different localities. Finally, Mr. John Murray discovered magnetic particles raised from the deposits at the bottom of the sea by H.M.S. *Challenger*. These particles were examined by Professor Alexander Herschel, who agreed with Mr. Murray in ascribing a cosmic origin to these particles. For fuller details and all references we must refer to Mr. Ranyard's paper.

Some interesting papers have also been published by Professors Silvestri and Tacchini.[6]

There can be little doubt that magnetic dust, which in all probability derives its origin from meteors, has often been observed, though it ought to be mentioned that some writers have come to a contrary conclusion.[7] The question arises in what way we can exercise our knowledge on these points to an appreciable extent.

A further series of occasional observations would in all probability lead to no result of great value unless the observations were continued

[1] 'On Waves,' *Phil. Mag.* (5), i. p. 257 (1876).

[2] 'On Stationary Liquid Waves,' *Phil. Mag.* (4), l. pp. 290. 377 (1875); see also Rayleigh in *Nature*, xii. p. 251.

[3] 'Versuch einer mathematischen Darstellung der Flüssigkeitswellen,' *Schl. Zeits. für Math.*, xxii. p. 133.

[4] 'Ueber stehende Schwingungen einer schweren Flüssigkeit,' *Wied. Ann.*, x. p. 34; also *Monatsber. d. k. akad. d. Wiss. zu Berl.*, May 15, 1879. For experiments bearing on this theory see a paper by Kirchhoff and Hansemann in the same journal, 'Versuche über stehende Schwingungen des Wassers,' *ib.*, p. 337.

[5] *Monthly Notices*, xxxix. p. 161 (1879).

[6] *Annali della Meteorologia*, Parte III. 1879.

[7] Flögel, *Zeitschrift für Meteorologie*, August 1881.

over a considerable length of time, and carried on in places specially adapted for the purpose.

For we know that meteoric dust does fall, and further observations ought, if possible, to be directed rather towards an approximate estimate of the quantity which falls within a given time. Difficulties very likely will be found in the determination of the locality in which the observations should be conducted. The place ought to be sheltered as much as possible against any ordinary dust not of meteoric origin. The lonely spots best fitted for these observations are generally accessible to occasional experiments only, and do not lend themselves easily to a regular series of observations. Nevertheless, experiments continued for a few months at some elevated spot in the Alps might lead to valuable results.

The Committee would like to draw attention to an instrument which might be well fitted for such observations. It was devised by Dr. Pierre Miquel for the purpose of examining, not the meteoric particles, but organic and organised matters floating about in the air. A description, with illustrations, will be found in the 'Annuaire de Montsouris' for 1879.

Two forms of the instrument are given. In the first form, which is only adapted to permanent places of observation, an aspirator draws a quantity of air which can be measured through a fine hole. The air impinges on a plate coated with glycerine, which retains all solid matter. By means of this instrument we may determine the quantity of solid particles within a given volume of air.

The second more portable form does not allow such an accurate quantitative analysis. The instrument is attached to a weathercock, and thus is always directed against the wind, which traverses it, and deposits, as in the other permanent form, its solid matter on a glycerine plate. An anemometer placed in the vicinity serves to give an approximate idea of the quantity of air which has passed through the apparatus. These instruments have been called aeroscopes by their inventor.

But perhaps the simpler plan of exposing a large horizontal surface covered with glycerine, and examining the dust deposited on it, will prove the most efficient for the purpose which the Committee has in view.

Second Report of the Committee, consisting of the Rev. SAMUEL HAUGHTON, *M.D., F.R.S., and* BENJAMIN WILLIAMSON, *F.R.S., appointed for the Calculation of Sun-heat Coefficients. Drawn up by* Dr. HAUGHTON.

THE Committee placed upon the table the volume of calculations relative to the equator, as a specimen of the five volumes which will ultimately be placed, for reference, in the library of Trinity College, Dublin; and explained the method by which the reductions had been made.

The formulæ, by means of which the calculations were made, have been published in the British Association Report for the Sheffield meeting (1879), and the Royal Irish Academy have undertaken the publication of all the summarised results in detail, so that it will not be necessary to ask the Association to undergo the expense of printing them.

Note on Method of Reduction.

1°. Time spent by the sun in every zone of altitude, one degree broad, on each day of the year, is calculated.

2°. These all added together should give a sum equal to half the year, or

262,980 minutes.

They actually give

263,020 minutes,

being an error of 40 minutes in the whole year.

3°. Supposing the error equally distributed in all the ninety zones; a correction is made by a multiplier, and the approximate true time spent by the sun in each zone is found.

4°. These times are then multiplied by the heat-coefficients of each zone, already published (Sheffield).

5°. The total heat received is represented by 27,038·425.

6°. The total heat received, if there were no atmosphere, is 40,171·391.

7°. The heat received at the earth's surface at the equator is therefore only 67·55 per cent. of that received at the surface of the atmosphere.

Fourteenth Report of the Committee, consisting of Professor EVERETT, Professor Sir WILLIAM THOMSON, Mr. G. J. SYMONS, Professor RAMSAY, Professor GEIKIE, Mr. J. GLAISHER, Mr. PENGELLY, Professor EDWARD HULL, Dr. CLEMENT LE NEVE FOSTER, Professor A. S. HERSCHEL, Professor G. A. LEBOUR, Mr. A. B. WYNNE, Mr. GALLOWAY, Mr. JOSEPH DICKINSON, Mr. G. F. DEACON, Mr. E. WETHERED, *and* Mr. A. STRAHAN, *appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water. Drawn up by* Professor EVERETT (*Secretary*).

SIX observations in the Talargoch Lead Mine, Flintshire, were given in last Report, and another has since been taken at a point distant 400 yards to the S.S.W. from Station VI. there mentioned. The depth beneath the surface of the ground is 220 yards, and the position is in a level going west from the engine-shaft. It was 3 yards from the forebreast, and had only been exposed nine days. The level was dry and there was not much circulation of air. The thermometer (one of the Committee's slow-action instruments) was inserted in a hole 25 inches deep, which was plugged with rag and 12 inches of clay after its insertion. It was withdrawn and read on three several occasions, July 19, 23, and 27, and on each occasion the temperature found was 62° Fahr.

Assuming, as in last year's Report, that 48° is the mean temperature at the surface, this would give an increase of 14° in 660 feet, or of 1° for 47 feet. The rock is white limestone with a little chert.

Comparing this observation with the other six, which exhibited great discordances among themselves, the discordance is still further increased, this last station being relatively hotter than any of the others. Though only 24 feet deeper than Station VI., it is 3·2° warmer; and Station VI. was itself exceptionally warm.

It is evident that there are local sources of disturbance which render this spot unsuitable for obtaining average results. The observation itself may be relied upon as correct, having been made by the captain of the mine, Mr. J. Lean, who assisted Mr. Strahan in last year's observations.

Mr. E. Garside, engineering student, Queen's College, Belfast, has continued his observations in the East Manchester coal-field.

In Ashton Moss Colliery, the temperature was observed on June 27 at the depth of 930 yards, and found to be 85·3°, the thermometer being inserted in a hole 2 inches in diameter and $3\frac{1}{2}$ feet deep, drilled for the purpose in hard blue shale which lies below the Great Mine coal seam, being newly-opened ground, dry, and free from cracks. The hole was allowed to stand ten or fifteen minutes, that the heat of drilling might partially escape, and one of the Committee's slow-action thermometers was then inserted with proper plugging, and left in for six hours. It was not considered advisable to leave it longer, as, 'owing to the great crush and unsettled state of the ground,' there might have been difficulty in extracting it. Up to the time at which the thermometer was withdrawn, no disturbance of the solidity of the ground had occurred. The tunnel, and especially this part of it, was free from the action of any strong air-current.

Assuming 49° as the surface-temperature, we have here an increase of 36·3° in 2,790 feet, which is at the rate of 1° in 76·9 feet.

Earlier observations were taken, at the depths of 871 and 897 yards, by the colliery engineer; but Mr. Garside reports that the thermometer with which they were taken was an ordinary cheap one with wood scale, and that on examination the tube was found to be a little loose in the scale. It seems best therefore to neglect them as unreliable.

In reference to an apprehension which was expressed that the heat of drilling had not had sufficient time to escape, Mr. Garside writes that he has on several occasions made a second observation in the same hole in places where he knew that the strata would stand and not crack, and he has always found the temperature unchanged; but that it is impossible to repeat the observation at such great depths as that of Ashton Moss, as in a few hours the holes became crooked.

Mr. Garside's next observation was at Bredbury Colliery (in the county of Cheshire), at the depth of 340 yards. A hole was drilled, as before, in dry warren earth (an argillaceous rock) free from cracks or water, in New Mine south level; and the temperature, observed as before, was 62°.

Assuming (as above) 49° as the surface-temperature, we have here an increase of 13° in 1,020 feet, which is at the rate of 1° in 78·5 feet.

The distance from Ashton Moss Colliery is three or four miles, and the two shafts are sunk through the same coal-measures, one being near the outcrop, and the other more on the deep.

Making no assumption as to surface-temperature, but comparing the two observations with each other, we have an increase of 23·3° in 1,770 feet, which is at the rate of 1° in 76·0 feet. The consistency of these results is eminently satisfactory.

On a subsequent date, July 19, Mr. Garside took the temperature at Nook Pit, belonging to the Broad Oak Colliery Company, at the depth of

350 yards, in the floor of the Royley Mine. It is in newly opened ground, free from cracks or other visible irregularities, at the far end of the newly opened North Level. The depth of the hole, which was in hard warren earth, and the other conditions of observation, were the same as before, and the temperature observed was $62\frac{1}{3}$° Fahr.

Taking the surface-temperature as 49°, this gives an increase of $13\frac{1}{3}$° in 1,050 feet, or of 1° for 79 feet.

All these stations, as well as Dukinfield, where Mr. Garside last year obtained results in good agreement with those now presented, are within a few miles of each other and close to the river Tame, which is here the boundary between Lancashire and Cheshire. Mr. Garside calls attention to the great quantity of water which is found in some parts of the rock overlying the coal-measures in this district, a source which is largely drawn upon for water-supply, and suggests, with much show of reason, that its presence may account for the slowness of the rate of increase shown by all these observations.

Mr. James M'Murtrie, general manager of the Radstock Collieries, near Bath, has taken observations in three different pits belonging to these collieries. The instrument used in each case was one of the Committee's slow-acting thermometers, placed in a hole drilled 2 feet deep, which was plugged with about 4 inches of clay. A moderate current of air was passing. The level, in each case, was dry and free from cracks, and the face at the place where the hole was drilled had only been exposed a day or two. The rocks overhead consist of lias above, then new red sandstone, and under this the shales and sandstones of the coal-measures. The mines, speaking generally, are comparatively dry, and the strata were perfectly dry where the temperatures were taken. There are no great hills near, the Mendips being about six miles distant, and the surface rises about one in fifty towards them, leaving out of account local undulations. The strata in all three cases were nearly level.

In Wells May Pit, the thermometer was left two days in a hole drilled in the sandstone rock at the depth of 560 feet, and read 61·7°.

In Ludlow's Pit, it was left two days in a hole drilled in the Bull Vein coal, at the depth of 1,000 feet, and read 63°.

In the same pit it was left five days in a hole drilled in the Middle Vein coal, at the depth of 810 feet, and read 63°.

All these observations were taken in June and July of the present year. Arranging them in order of depth, and assuming the surface-temperature to be 50°, the result stands thus:—

Depth in feet	Temperature Fahr.	Excess over surface	Feet per degree
560	61·7	11·7	48
810	63	13	62
1000	63	13	77

They exhibit a large amount of irregularity, which is not easily accounted for. The mean result may be taken as 1° in 62 feet. Mr. Wethered's observations in the Kingswood Collieries, near Bristol (see 'Report' for 1879), gave about 1° in 68 feet.

Report of the Committee, consisting of Mr. G. H. DARWIN, Professor Sir WILLIAM THOMSON, Professor TAIT, Professor GRANT, Dr. SIEMENS, Professor PURSER, Professor G. FORBES, *and* Mr. HORACE DARWIN, *appointed for the Measurement of the Lunar Disturbance of Gravity.*

On an instrument for detecting and measuring small changes in the direction of the force of gravity, by GEORGE H. DARWIN, *M.A., F.R.S., formerly Fellow of Trinity College, Cambridge, and* HORACE DARWIN, *M.A., Assoc. M. Inst. C.E.*

[This report is written in the name of G. H. DARWIN merely for the sake of verbal convenience.]

I. *Account of the experiments.*

WE feel some difficulty as to the form which this report should take, because we are still carrying on our experiments, and have, as yet, arrived at no final results. As, however, we have done a good deal of work, and have come to conclusions of some interest, we think it better to give at once an account of our operations up to the present time, rather than to defer it to the future.

In November, 1878, Sir William Thomson suggested to me that I should endeavour to investigate experimentally the lunar disturbance of gravity, and the question of the tidal yielding of the solid earth. In May, 1879, we both visited him at Glasgow, and there saw an instrument, which, although roughly put together, he believed to contain the principle by which success might perhaps be attained. The instrument was erected in the Physical Laboratory of the University of Glasgow. We are not in a position to give an accurate description of it, but the following rough details are quite sufficient.

A solid lead cylinder, weighing perhaps a pound or two, was suspended by a fine brass wire, about 5 feet in length, from the centre of the lintel or cross-beam of the solid stone gallows, which is erected there for the purpose of pendulum experiments. A spike projected a little way out of the bottom of the cylindrical weight; a single silk fibre, several inches in length, was cemented to this spike, and the other end of the fibre was cemented to the edge of an ordinary galvanometer-mirror. A second silk fibre, of equal length, was cemented to the edge of the mirror at a point near to the attachment of the former fibre. The other end of this second fibre was then attached to a support, which was connected with the base of the stone gallows. The support was so placed that it stood very near to the spike at the bottom of the pendulum, and the mirror thus hung by the bifilar suspension of two silks, which stood exceedingly near to one another in their upper parts. The instrument was screened from draughts by paper pasted across between the two pillars of the gallows; but at the bottom, on one side, a pane of glass was inserted, through which one could see the pendulum-bob and galvanometer-mirror.

It is obvious that a small displacement of the pendulum, in a direction perpendicular to the two silks, will cause the mirror to turn about a vertical axis.

A lamp and slit were arranged, as in a galvanometer, for exhibiting the movement of the pendulum, by means of the beam of light reflected from the mirror.

No systematic observations were made, but we looked at the instrument at various hours of the day and night, and on Sunday also, when the street and railway traffic is very small.

The reflected beam of light was found to be in incessant movement, of so irregular a character that it was hardly possible to localise the mean position of the spot of light on the screen, within 5 or 6 inches. On returning to the instrument after several hours, we frequently found that the light had wandered to quite a different part of the room, and we had sometimes to search through nearly a semicircle before finding it again.

Sir William Thomson showed us that, by standing some 10 feet away from the piers, and swaying from one foot to the other, in time with the free oscillations of the pendulum, quite a large oscillation of the spot of light could be produced. Subsequent experience has taught us that considerable precautions are necessary to avoid effects of this kind, and the stone piers at Glasgow did not seem to be well isolated from the floor, and the top of the gallows was used as a junction for a number of electric connections.

The cause of the extreme irregularity of the movements of the pendulum was obscure; and as Sir William Thomson was of opinion that the instrument was well worthy of careful study, we determined to undertake a series of experiments at the Cavendish Laboratory at Cambridge. We take this opportunity of recording our thanks to Lord Rayleigh[1] for his kindness in placing rooms at our disposal, and for his constant readiness to help us.

The pressure of other employments on both of us prevented our beginning operations immediately, and the length of time which we have now spent over these experiments is partly referable to this cause, although it is principally due to the number of difficulties to be overcome, and to the quantity of apparatus which has had to be manufactured.

In order to avoid the possibility of disturbance from terrestrial magnetism, we determined that our pendulum should be made of pure copper.[2] Mr. Hussey Vivian kindly gave me an introduction to Messrs. Elkington, of Birmingham; and, although it was quite out of their ordinary line of business, they consented to make what we required. Accordingly, they made a pair of electrolytically-deposited solid copper cylinders, $5\frac{1}{2}$ inches long, and $2\frac{3}{4}$ inches in diameter. From their appearance, we presume that the deposition was made on to the inside of copper tubes, and we understand that it occupied six weeks to take place. In November, 1879, they sent us these two heavy masses of copper, and, declining any payment, courteously begged our acceptance of them. Of these two cylinders we have, as yet, only used one; but should our present endeavours lead to results of interest, we shall ultimately require both of them.

Two months before the receipt of our weights, the British Association had reappointed the Committee for the Lunar Disturbance of Gravity, and had added our names thereto. Since that time, with the exception

[1] Professor Maxwell had given us permission to use the 'pendulum room,' but we had not yet begun our operations at the time of his death.

[2] We now think that this was probably a superfluity of precaution.

of compulsory intermissions, we have continued to work at this subject. My brother Horace and I have always discussed together the plan on which to proceed; but up to the present time much the larger part of the work has consisted in devising mechanical expedients for overcoming difficulties. In this work he has borne by very far the larger share; and the apparatus has been throughout constructed from his designs, and under his superintendence, by the Cambridge Scientific Instrument Company.

Near the corner of a stone-paved ground-floor room in the Cavendish Laboratory there stands a very solid stone gallows, similar to, but rather more massive than, the one at Glasgow. As it did not appear thoroughly free from rigid connection with the floor, we had the pavement raised all round the piers, and the earth was excavated from round the brick basement to the depth of about 2 feet 6 inches, until we were assured that there was no connection with the floor or walls of the room, excepting through the earth. The ditch, which was left round the piers, was found very useful for enabling us to carry out the somewhat delicate manipulations involved in hanging the mirror by its two silk fibres.

Into the middle of the flat ends of one of our copper weights (which weighed 4,797 grammes, with spec. gr. 8·91) were screwed a pair of copper plugs; one plug was square-headed and the other pointed. Into the centre of the square plug was soldered a thin copper wire, just capable of sustaining the weight, and intended to hang the pendulum.

A stout cast-iron tripod was made for the support of the pendulum. Through a hole in the centre of it there ran rather loosely a stout iron rod with a screw cut on it. A nut ran on the screw and prevented the rod from slipping through the hole. The other end of the copper wire was fixed into the end of the rod.

The tripod was placed with its three legs resting near the margin of the circular hole in the centre of the lintel of the gallows. The iron rod was in the centre of the hole, and its lower end appeared about six inches below the lower face of the lintel. The pendulum hung from the rod by a wire of such length as to bring the spiked plug within a few inches of the base of the gallows. This would of course be a very bad way of hanging a pendulum which is intended to swing, but in our case the displacements of the end of the pendulum were only likely to be of a magnitude to be estimated in thousandths or even millionths of an inch, and it is certain that for such small displacements the nut from which the pendulum hung could not possibly rock on its bearings. However, in subsequent experiments we improved the arrangement by giving the nut a flange, from which there projected three small equidistant knobs, on which the nut rested.

The length of the pendulum from the upper juncture with the iron rod down to the tip of the spike in the bob was 148·2 c.m.

An iron box was cast with three short legs, two in front and one behind; its interior dimensions were $15 \times 15 \times 17\frac{1}{2}$ c.m.; it had a tap at the back; the front face ($15 \times 17\frac{1}{2}$) was left open, with arrangements for fixing a plate-glass face thereon. The top face ($15 \times 17\frac{1}{2}$) was pierced by a large round hole. On to this hole was cemented an ordinary earthenware 4-inch drain pipe, and on to the top of this first pipe there was cemented a second. The box was thus provided with a chimney 144 c.m. high. The cubic contents of the box and chimney were about $3\frac{1}{2}$ gallons.

The box was placed standing on the base of the gallows, with the chimney vertically underneath the round hole in the lintel. The top of the chimney nearly reached the lower face of the lintel, and the iron rod of the pendulum extended a few inches down into the chimney. The pendulum wire ran down the middle of the chimney, and the lower half of the pendulum bob was visible through the open face of the iron box. The stone gallows faces towards the S.E., but we placed the box askew on the base, so that its open face was directed towards the S.

The three legs of the box rested on little metal discs, each with a conical hole in it, and these discs rested on three others of a somewhat larger size. When the box was set approximately in position, we could by an arrangement of screws cause the smaller discs to slide a fraction of an inch on the larger ones, and thus exactly adjust the position of the box and chimney.

A small stand, something like a retort stand, about 4 inches high, stood on a leaden base, with a short horizontal arm clamped by a screw on to the thin vertical rod. This was the 'fixed' support for the bifilar suspension of the mirror. The stand was placed to the E. of the pendulum bob, and the horizontal arm reached out until it came very close to the spike of the pendulum.

The suspension and protection from tarnishing of our mirror gave us much trouble, but it is useless to explain the various earlier methods employed, because we have now overcome these difficulties in a manner to be described later. The two cocoon fibres were fixed at a considerable distance apart on the edge of the mirror, and as they were very short they splayed out at nearly a right angle to one another. By means of this arrangement the free period of oscillation of the mirror was made very short, and we were easily able to separate the long free swing of the pendulum from the short oscillations of the mirror.

The mirror was hung so that the upper ends of the silks stood within an eighth of an inch of one another, but the tip of the spike stood $\frac{1}{8}$ or $\frac{1}{16}$ of an inch higher than the fixed support. The plate-glass front of the box was then fixed on with indiarubber packing.

It is obvious that a movement of the box parallel to the front from E. to W. would bring the two fibres nearer together; this operation we shall describe as sensitising the instrument. A movement of the box perpendicular to the front would cause the mirror to show its face parallel to the front of the box; this operation we shall describe as centralising. As sensitising will generally decentralise, both sets of screws had to be worked alternately.

The adjusting screws for moving the box did not work very well; nevertheless, by a little trouble we managed to bring the two silks of the bifilar suspension very close to one another.

After the instrument had been hung as above described, we tried a preliminary sensitisation, and found the pendulum to respond to a slight touch on either pier. The spot of light reflected from the mirror was very unsteady, but not nearly so much so as in the Glasgow experiment; and we were quite unable to produce any perceptible increase of agitation by stamping or swaying to and fro on the stone floor. This showed that the isolation of the pier was far more satisfactory than at Glasgow.

We then filled the box and pipes with water. We had much trouble with slow leakage of the vessel, but the most serious difficulty arose from the air-bubbles which adhered to the pendulum. By using boiled water we obviated this fairly well, but we concluded that it was a great mistake to have a flat bottom to the pendulum. This mistake we have remedied in the final experiment described in the present paper.

The damping effect of the water on the oscillations of the pendulum and of the mirror was very great, and although the incessant dance of the light continued, it was of much smaller amplitude, and comparatively large oscillations of the pendulum, caused by giving the piers a push, died out after two or three swings. A very slight push on the stone piers displaced the mean position of the light, but jumping and stamping on the pavement of the room produced no perceptible effect. If, however, one of us stood on the bare earth in the ditch behind, or before the massive stone pier, a very sensible deflection of the light was caused; this we now know was caused by an elastic depression of the earth, which tilted the whole structure in one or the other direction. A pull of a few ounces, delivered horizontally on the centre of the lintel, produced a clear deflection, and when the pull was 8lbs., the deflection of the spot of light amounted to 45 c.m. We then determined to make some rough systematic experiments.

The room was darkened by shutters over all the windows, and the doors were kept closed. The paraffin lamp stood at three or four feet to the S.E. of the easterly stone pier, but the light was screened from the pier.

We began our readings at 12 noon (March 15, 1880), and took eight between that time and 10.30 P.M. From 12 noon until 4 P.M. the lamp was left burning, but afterwards it was only lighted for about a minute to take each reading. At 12 the reading was 595 m.m., and at 4 P.M. it was 936 m.m.[1]; these readings, together with the intermediate ones, showed that the pendulum had been moving northwards with a nearly uniform velocity. After the lamp was put out, the pendulum moved southward, and by 10.30 P.M. was nearly in the same position as at noon.

During the whole of the two following days and a part of the next we took a number of readings from 9 A.M. until 11 P.M. The observations when graphically exhibited showed a fairly regular wave, the pendulum being at the maximum of its northern excursion between 5 and 7 P.M., and probably furthest south between the same hours in the morning. But besides this wave motion, the mean position for the day travelled a good deal northward. We think that a part of this diurnal oscillation was due to the warping of the stone columns from changes of temperature. An increase of temperature on the south-east faces of the piers carried the lintel towards the north-west, and of this displacement we observed only the northerly component. The lamp produced a very rapid effect, and the diurnal change lagged some two hours behind the change in the external air. The *difference* between the temperatures of the S.E. and N.W. faces of the pier must have been very slight indeed. At that time, and indeed until quite recently, we attributed the whole of this diurnal oscillation to the warping of the piers, but we now feel nearly certain that it was due in great measure to a real change in the horizon.

We found that warming one of the legs of the iron tripod, even by contact with the finger, produced a marked effect, and we concluded that the mode of suspension was unsatisfactory.

[1] I give the numbers as recorded in the note-book, but the readings would sometimes differ by 2 or 3 m.m. within half-a-minute. The light always waves to and fro in an uncertain sort of way, so that it is impossible to assign a mean position with any certainty.

Although we had thus learnt that changes of temperature formed the great obstacle in the way of success, there were a good many things to be learnt from the instrument as it existed at that time.

After the box and pipes had been filled for some days the plate-glass front cracked quite across, and a slow leakage began to take place; we were thus compelled to dismount the whole apparatus and to make a fresh start.

It is obvious that to detect and measure displacements of the pendulum in the N. and S. direction, the azimuth of the silks by which the mirror is suspended must be E. and W., and that although any E. and W. displacement of the pendulum will be invisible, still such displacement will alter the sensitiveness of the instrument for the N. and S. displacements. In order to obviate this we determined to constrain the pendulum to move only in the N. and S. azimuth.

Accordingly we had a T-piece about 4 inches long fixed to the end of the iron rod from which the pendulum hung. The two ends of a fine copper wire were soldered into the ends of the T-piece; a long loop of wire was thus formed. The square-headed plug at the top of the pendulum-bob was replaced by another containing a small copper wheel, which could revolve about a horizontal axis. The bearings of the wheel were open on one side.

When the wheel was placed to ride on the bottom of the wire loop, and the pendulum-bob hooked on to the axle of the wheel by the open bearings, we had our pendulum hanging by a bifilar suspension. The motion of the pendulum was thus constrained to take place only perpendicular to the plane of the wire loop.

The iron tripod was replaced by a slate slab large enough to entirely cover the hole in the lintel of the gallows. Through the centre of the slab was a round hole, of about one inch in diameter, through which passed the iron rod with the T-piece at the lower end. The iron rod was supported on the slate by means of the flanged nut above referred to. There was also a straight slot, cut quite through the slab, running from the central hole to the margin. The purpose of this slot will be explained presently.

In the preceding experiment we had no means of determining the absolute amount of displacement of the pendulum, although, of course, we knew that it must be very small. There are two methods by which the absolute displacements are determinable; one is to cause known small displacements to the pendulum and to watch the effect on the mirror; and the second is to cause known small horizontal forces to act on the pendulum. We have hitherto only employed the latter method, but we are rather inclined to think that the former may give better results.

The following plan for producing small known horizontal forces was suggested by my brother.

Suppose there be a very large and a very small pendulum hanging by wires of equal length from neighbouring points in the same horizon; and suppose the large and the small pendulum to be joined by a fibre which is a very little shorter than the distance between the points of suspension. Then each pendulum is obviously deflected a little from the vertical, but the deflection of the small pendulum varies as the mass of the larger, and that of the larger as the mass of the smaller. If m be the mass of the small pendulum, and M of the large one, and if a be the distance between the points of suspension, then it may be easily shown that if a be increased by a small length δa, the increase of the linear deflection of the large pendulum is $m\delta a/(m+M)$. If l be the length of either pendulum, the angular deflection of the larger one is $m\delta a/l(m+M)$, and this is the deflection which would be produced by a horizontal force equal to $m\delta a/l(m+M)$ of gravity. It is clear, then, that by making the inequality between the two weights m and M very great, and the displacement of the point of suspension very small, we may deflect the large pendulum by as small a quantity as we like. The theory is almost the same if the two pendulums are not of exactly the same length, or if the length of one of them be varied.

Now in our application of this principle we did not actually attach the two pendulums together, but we made the little pendulum lean up against the large one; the theory is obviously just the same.

We call the small pendulum 'the disturber,' because its use is to disturb the large pendulum by known forces. A small copper weight for the disturber weighed ·732 grammes, and the large pendulum-bob, with its pulley, weighed 4831·5. Therefore the one was 6600 times as massive as the other. The disturber was hung by a platinum wire about $\frac{1}{1000}$th of an inch in diameter, which is a good deal thinner than a fine human hair.

We must now explain how the disturber was suspended, and the method of moving its point of suspension.

Parallel to the sides of the slot in the slate slab there was riveted a pair of brass rails, one being V-shaped and the other flat; on these rails there slid a little carriage with three legs, one of which slid on one rail, and the other two on the other. A brass rod with an eyelet-hole at the end was fixed to the centre of the carriage, and was directed downwards so that it passed through the centre of the slot. The slot was directed so that it was perpendicular to the T-piece from which the pendulum hung, and the brass rod of the little carriage was bent and of such length, that when the carriage was pushed on its rails until it was as near the centre of the slab as it would go, the eyelet-hole stood just below the T-piece, and half-way between the two wires. A micrometer screw was clamped to the slab and was arranged for making the carriage traverse known lengths on its rails, and as the wires of the pendulum were in the E. and W. plane, the carriage was caused to travel N. and S. by its micrometer screw.

One end of the fine platinum wire was fastened to the eyelet, and the other (as above stated) to the small disturbing weight. The platinum wire was of such length that the disturber just reached the pulley by which the big pendulum hung. We found that by pushing the carriage up to the centre, and very slightly tilting it off one rail, we could cause the disturber-weight to rest on either side of the pulley at will. If it was left on the side of the pulley remote from the disturber-carriage, it was in gear, and the traversing of the carriage on its rails would produce a small pressure of the disturber on to the side of the pulley. If it was left on the same side of the pulley as the disturber-carriage, the two pendulums were quite independent and the disturber was out of gear.

On making allowance for the difference in length between the pendulum and the disturber, and for the manner in which the thrust was delivered at the top of the pendulum, but omitting the corrections for the weights of the suspending wires and for the elasticity of the copper wire, we found that one turn of the micrometer screw should displace the spike at the bottom of the pendulum through 0·0001 mm. or $\frac{1}{245000}$th of an inch. The same displacement would be produced by an alteration in the direction of gravity with reference to the earth's surface by $\frac{1}{70}$th of a second of arc.

A rough computation showed that the to and fro motion of the pendulum in the N.S. azimuth, due to lunar attraction, should, if the earth be rigid, be the same as that produced by $2\frac{2}{3}$ turns of the micrometer screw.

We now return to the other arrangements made in re-erecting the instrument.

A new mirror, silvered on the face, was used, and was hung in a slightly different manner.

The fluid in which the pendulum was hung was spirits and water. The physical properties of such a mixture will be referred to later. In order to avoid air-bubbles we boiled $3\frac{1}{2}$ gallons of spirits and water for three hours *in vacuo*, and the result appeared satisfactory in that respect.

After the mirror was hung, the plate-glass front to the box was fixed and the vessel was filled by the tap in the back of the box. The disturber was not introduced until afterwards, and we then found that the pendulum responded properly to the disturbance.

As the heat of a lamp in the neighbourhood of the piers exercised a large disturbance, we changed the method of observing, and read the reflection of a scale with a telescope. The scale was a levelling staff divided into feet, and tenths and hundredths of a foot, laid horizontally at 15 feet from the piers, with the telescope immediately over it.

Since the amount of fluid through which the light had to pass was considerable, we were forced to place a gas-flame immediately in front of the scale; but the gas was only kept alight long enough to take a reading.

After sensitising the instrument we found that the incessant dance of the image of the scale was markedly less than when the pendulum was hung in water. A touch with a finger on either pier produced deflection by bending the piers, and the instrument responded to the disturber.

The vessel had been filled with fluid for some days, and we had just begun a series of readings, when the plate-glass front again cracked quite across without any previous warning. Thus ended our second attempt.

In the third experiment (July and August, 1880) the arrangements were so nearly the same as those just described that we need not refer to them. The packing for the plate-glass front was formed of red lead, and this proved perfectly successful, whereas the indiarubber packing had twice failed. As we were troubled by invisible leakage and by the evaporation of the fluid, we arranged an inverted bottle, so as always to keep the chimney full. We thought that when the T-piece at the end of the shaft became exposed to the air, the pendulum became much more unsteady, but we now think it at least possible that there was merely a period of real terrestrial disturbance.

From August 10 to 14 we took a series of observations from early morning until late at night. We noted the same sort of diurnal oscillatory motion as before, but the outline of the curve was far less regular. This, we think, may perhaps be explained by the necessity we were under of leaving the doors open a good deal, in order to permit the cord to pass by which Lord Rayleigh was spinning the British Association coil.

Notwithstanding that the weather was sultry the warping of the stone columns must have been very slight, for a thermometer hung close to the pier scarcely showed a degree of change between the day and night, and the *difference* of temperature of the N. and S. faces must have been a very small fraction of a degree. At that time, however, we still thought that the whole of the diurnal oscillation was due to the warping of the columns.

We next tried a series of experiments to test the sensitiveness of the instrument.

As above remarked the image of the scale was continually in motion, and moreover the mean reading was always shifting in either one direction or the other. At any one time it was possible to take a reading to within $\frac{1}{10}$th of a foot with certainty, and to make an estimate of the $\frac{1}{100}$th of a foot, but the numbers given below are necessarily to be regarded as very rough approximations.

As above stated, the gallows faced about to the S.E., and we may describe the two square piers as the E. and W. piers, and the edges of each pier by the points of the compass towards which they are directed.

On August 14, 1880, my brother stood on a plank supported by the pavement of the room close to the S.W. edge of the W. pier, and, lighting a spirit lamp, held the flame for ten seconds within an inch or two of this edge of the pier. The effect was certainly produced of making the pendulum-bob move northwards, but as such an effect is fused in the diurnal change then going on, the amount of effect was uncertain. He then stood similarly near the N.E. edge of the E. pier, and held the spirit flame actually licking the edge of the stone during one minute. The effect should now be opposed to the diurnal change, and it was so. Before the exposure to heat was over the reading had decreased ·15 feet, and after the heat was withdrawn the recovery began to take place almost immediately. We concluded afterwards that the effect was equivalent to a change of horizon of about $0''\cdot15$.

When the flame was held near but not touching the lintel for thirty seconds, the effect was obvious but scarcely measurable, even in round numbers, on account of the unsteadiness of the image.

When a heated lump of brass was pushed under the iron box no effect whatever was perceived, and even when a spirit flame was held so as to lick one side of the iron box during thirty seconds, we could not be sure that there was any effect. We had expected a violent disturbance, but these experiments seemed to show that convection currents in the fluid produce remarkably little effect.

When a pull of 300 grammes was delivered on to the centre of the lintel in a southward direction, we determined by several trials that the displacement of the reading was about ·30 feet, which may be equal to about $0''\cdot3$ change of horizon.

Two-thirds of a watering-can of water was poured into the ditch at the back of the pier. In this experiment the swelling of the ground should have an effect antagonistic to that produced by the cooling of the back face of the pier, and also to the diurnal changes then going on. The swelling of the ground certainly tilted the pier over, so that the reading was altered by ·10 foot. A further dose of water seemed to have the same effect, and it took more than an hour for the piers to regain their former position. As the normal diurnal change was going on simultaneously, we do not know the length of time during which the water continued to produce an effect.

On August 15 we tried a series of experiments with the disturber. When the disturber was displaced on its rails, the pendulum took a very perceptible time to take up its new position, on account of the viscosity of the fluid in which it was immersed.

The diurnal changes which were going on prevented the readings from being very accordant amongst themselves, but we concluded that twenty-five turns of the screw gave between ·4 foot and ·3 foot alteration in the reading on the scale. From the masses and dimensions of the pendulum and disturber, we concluded that 1 foot of our scale corresponded with about 1″ change in horizon. Taking into account the length of the pendulum, it appeared that 1 foot of our scale corresponded with $\frac{1}{1400}$th of a mm. displacement of the spike at the bottom of the pendulum. Now as a tenth of a foot of alteration of reading could be perceived with certainty, it followed that when the pendulum point moved through $\frac{1}{14000}$th of a mm. we could certainly perceive it.

During the first ten days the mean of the diurnal readings gradually increased, showing that the pendulum was moving northwards, until the reading had actually shifted 8 feet on the scale. It then became necessary to shift the scale. Between August 23 and 25 the reading had changed another foot. We then left Cambridge. On returning in October we found that this change had continued. The mirror had, however, become tarnished, and it was no longer possible to take a reading, although one could just see a gas flame by reflection from the mirror.

Whilst erecting the pendulum we had to stand on, and in front of, the piers, and to put them under various kinds of stress, and we always found that after such stress some sort of apparently abnormal changes in the piers continued for three or four hours afterwards.

We were at that time at a loss to understand the reason of this long-continued change in the mean position of the pendulum, and were reluctant to believe that it indicated any real change of horizon of the whole soil; but after having read the papers of MM. d'Abbadie and Plantamour, we now believe that such a real change was taking place.

By this course of experiments it appeared that an instrument of the kind described may be brought to almost any degree of sensitiveness. We had seen, however, that a stone support is unfavourable, because the bad conductivity of stone prevents a rapid equalisation of temperature between different parts, and even small inequalities of temperature produce considerable warping of the stone piers. But it now seems probable that we exaggerated the amount of disturbance which may arise from this cause.

A cellar would undoubtedly be the best site for such an experiment, but unfortunately there is no such place available in the Cavendish Laboratory. Lord Rayleigh, however, placed the 'balance room' at our disposal, and this room has a northerly aspect. There are two windows in it, high up on the north wall, and these we keep boarded up.

The arrangements which we now intended to make were that the pendulum and mirror should be hung in a very confined space, and should be immersed in fluid of considerable viscosity. The boundary of that space should be made of a heat-conducting material, which should itself form the support for the pendulum. The whole instrument, including the basement, was to be immersed in water, and the basement itself was to be carefully detached from contact with the building in which it stands. By these means we hoped to damp out the short oscillations due to local tremors, but to allow the longer oscillations free to take place; but above all we desired that changes of temperature in the instrument should take place with great slowness, and should be, as far as possible, equal all round.

We removed the pavement from the centre of the room, and had a circular hole, about 3 feet 6 inches in diameter, excavated in the 'made earth,' until we got down to the undisturbed gravel, at a depth of about 2 feet 6 inches.

We obtained a large cylindrical stone 2 feet 4 inches in diameter and 2 feet 6 inches in height, weighing about three-quarters of a ton. This we had intended to place on the earth in the hole, so that its upper surface should stand flush with the pavement of the room. But the excavation had been carried down a little too deep, and therefore an ordinary flat paving stone was placed on the earth, with a thin bedding of cement underneath it. The cylindrical block was placed to stand upon the paving stone, with a very thin bedding of lime and water between the two stones. The surface of the stone was then flush with the floor. We do not think that any sacrifice of stability has been made by this course.

An annular trench or ditch a little less than a foot across is left round the stone. We have lately had the bottom of the ditch cemented, and the vertical sides lined with brickwork, which is kept clear of any contact with the pavement of the room. On the S. side the ditch is a little wider, and this permits us to stand in it conveniently. The bricked ditch is watertight, and has a small overflow pipe into the drains. The water in the ditch stands slightly higher than the flat top of the cylindrical stone, and thus the whole basement may be kept immersed in water, and it is, presumably, at a very uniform temperature all round.

Before describing the instrument itself we will explain the remaining precautions for equalisation of temperature.

On the flat top of the stone stands a large barrel or tub, 5 feet 6 inches high and 1 foot 10 inches in diameter, open at both ends. The diameter of the stone is about 2 inches greater than the outside measure of the diameter of the tub, and the tub thus nearly covers the whole of the stone. The tub is well payed with pitch inside, and stands on two felt rings soaked in tar. Five large iron weights, weighing altogether nearly three-quarters of a ton, are hooked on to the upper edge of the tub, in order to make the joint between the tub and the stone watertight. Near the bottom is a plate-glass window; when it is in position, the window faces to the S. This tub is filled with water and the instrument stands immersed therein.

We had at first much trouble from the leakage of the tub, and we have to thank Mr. Gordon, the assistant at the Laboratory, for his ready help in overcoming this difficulty, as well as others which were perpetually recurring. The mounting of the tub was one of the last things done before the instrument was ready for observation, and we must now return to the description of the instrument itself.

We used the same pendulum-bob as before, but we had its shape altered so that the ends both above and below were conical surfaces, whilst the central part was left cylindrical. The upper plug with its pulley is replaced by another plug bearing a short round horizontal rod, with a rounded groove cut in it. The groove stands vertically over the centre of the weight, and is designed for taking the wire of the bifilar suspension of the pendulum; when riding on the wire the pendulum-bob hangs vertically.

Part of this upper plug consists of a short thin horizontal arm about an inch long. This arm is perpendicular to the plane of the groove, and when the pendulum is in position, projects northwards. Through the end of the arm is bored a fine vertical hole. This part of the apparatus is for the modified form of disturber, which we are now using.

The support for the pendulum consists of a stout copper tube $2\frac{7}{8}$ inches in diameter inside measure, and it just admits the pendulum-bob with $\frac{1}{8}$th inch play all round. The tube is 3 feet 6 inches in height, and is closed at the lower end by a diaphragm, pierced in the centre by a round hole, about $\frac{1}{4}$ inch in diameter. The upper end has a ring of brass soldered on to it, and this ring has a flange to it. The upper part of the brass ring forms a short continuation $\frac{3}{4}$ of an inch in length of the copper tube. The ring is only introduced as a means of fastening the flange to the copper tube.

The upper edge of the brass continuation has three V notches in it at 120° apart on the circumference of the ring. A brass cap like the lid of a pill-box has an inside measure $\frac{1}{4}$ inch greater than the outside measure of the brass ring. The brass cap has three rods which project inwards from its circumference, and which are placed at 120° apart thereon. When the cap is placed on the brass continuation of the upper tube, the three rods rest in the three V notches, and the cap is geometrically fixed with respect to the tube. A fine screw works through the centre of the cap, and actuates an apparatus, not easy to explain without drawings, by which the cap can be slightly tilted in one azimuth. The object of tilting the cap is to enable us to sensitise the instrument by bringing the silk fibres attached to the mirror into close proximity.

Into the cap are soldered the two ends of a fine brass wire; the junctures are equidistant from the centre of the cap and on opposite sides of it; they lie on that diameter of the cap which is perpendicular to the axis about which the tilting can be produced.

When the pendulum is hung on the brass wire loop by the groove in the upper plug, the wires just clear the sides of the copper tube.

It is clear that the tilting of the cap is mechanically equivalent to a shortening of one side of the wire loop and the lengthening of the other. Hence the pendulum is susceptible of a small lateral adjustment by means of the screw in the cap.

To the bottom of the tube is soldered a second stout brass ring; this ring bears on it three stout brass legs inclined at 120° to one another, all lying in a plane perpendicular to the copper tube. From the extremity of each leg to the centre of the tube is $8\frac{1}{2}$ inches. The last inch of each leg is hollowed out on its under surface into the form of a radial V groove.

There are three detached short pieces of brass tube, each ending below in a flange with three knobs on it, and at the upper end in a screw with a rounded head. These three serve as feet for the instrument. These three feet are placed on the upper surface of our basement stone at 120° apart, estimated from the centre of the stone. The copper tube with its legs attached is set down so that the inverted V grooves in the legs rest on the rounded screw-head at the tops of the three feet, and each of the feet rests on its three knobs on the stone. The bottom of the copper tube is thus raised $5\frac{1}{2}$ inches above the stone. By this arrangement the copper tube is retained in position with reference to the stone, and it will be observed that no part of the apparatus is under any constraint except such as is just necessary to geometrically determine its position.

The screws with rounded heads which form the three feet are susceptible of small adjustments in height, and one of the three heads is capable of more delicate adjustment, for it is actuated by a fine screw, which is driven by a toothed wheel and pinion. The pinion is turned by a wooden rod, made flexible by the insertion of a Hook's joint, and the wooden rod reaches to the top of the tub, when it is mounted surrounding the instrument.

The adjustable leg is to the N. of the instrument, and as the mirror faces S. we call it the 'back-leg.' When the copper support is mounted on its three legs, a rough adjustment for the verticality of the tube is made with two of the legs, and final adjustment is made by the back-leg.

It is obvious that if the back-leg be raised or depressed the point of the pendulum is carried southwards or northwards, and the mirror turns accordingly. Thus the back-leg with its screw and rod affords the means of centralising the mirror. The arrangements for suspending the mirror must now be described.

The lower plug in the pendulum-bob is rounded and has a small horizontal hole through it. When the pendulum is hung this rounded plug just appears through the hole in the diaphragm at the bottom of the copper tube.

A small brass box, shaped like a disk, can be screwed on to the bottom of the copper tube, in such a way that a diameter of the box forms a straight line with the axis of the copper tube. One side of the box is of plate glass, and when it is fastened in position the plate glass faces to the S. This is the mirror-box; it is of such a size as to permit the mirror to swing about 15° in either direction from parallelism with the plate-glass front.

The fixed support for the second fibre for the bifilar suspension of the mirror may be described as a very small inverted retort-stand. The vertical rod projects downwards from the underside of the diaphragm, a little to the E. of the hole in the diaphragm; and a small horizontal arm projects from this rod, and is of such a length that its extremity reaches to near the centre of the hole. This arm has a small eyelet-hole pierced through a projection at its extremity.

The mirror itself is a little larger than a shilling and is of thin plate glass; it has two holes drilled through the edge at about 60° from one another. The mirror was silvered on both sides, and then dipped into melted paraffin; the paraffin and silver were then cleaned off one side. The paraffin protects the silver from tarnishing, and the silver film seen through the glass has been found to remain perfectly bright for months, after having been immersed in fluid during that time. A piece of platinum wire about $\frac{1}{1000}$th of an inch in diameter is threaded twice through each hole in opposite directions, in such a manner that with a continuous piece of wire (formed by tying the two ends together) a pair of short loops are formed at the edge of the mirror, over each of the two holes. When the mirror is hung from a silk fibre passing through both loops, the weight of the mirror is sufficient to pull each loop taut.

A single silk fibre was threaded through the eyelet-hole at the end of the blunt point of the pendulum-bob, and tied in such a way that there was no loose end projecting so as to foul the other side of the bifilar suspension. The other end of the silk fibre was knotted to a piece of sewing silk on which a needle was threaded.

The pendulum was then hung from the cap by its wire loop, outside the copper tube, and the silk fibre with the sewing silk and needle attached dangled down at the bottom. The cap, with the pendulum attached thereto, was then hauled up and carefully let down into the copper tube. The sewing silk, fibre, and blunt end came out through the hole in the diaphragm.

We then sewed with the needle through the two loops on the margin of the mirror, and then through the eyelet-hole in the little horizontal arm. The silk was pulled taut, and the end fastened off on to the little vertical rod, from which the horizontal arm projects.

The mirror then hangs with one part of the silk attached to the pendulum-bob and the other to the horizontal arm.

The two parts of the silk are inclined to one another at a considerable angle, so that the free period of the mirror is short, but the upper parts of the silk stand very close to one another. The mirror-box encloses the mirror and makes the copper tube watertight.

There is another part of the apparatus which has not yet been explained, namely, the disturber. This part of the instrument was in reality arranged before the mirror was hung.

We shall not give a full account of the disturber, because it does not seem to work very satisfactorily.

In the form of disturber which we now use the variation of horizontal thrust is produced by variation in the length of the disturbing pendulum, instead of by variation of the point of support as in the previous experiment. It was not easy to vary the point of support when the pendulum is hung in a tube which nearly fits it.

The disturber-weight is a small lump of copper, and it hangs by fine sewing silk. The silk is threaded through the eyelet in the horizontal arm which forms part of the upper plug of the pendulum; thus the disturber-weight is to the N. of the pendulum. The silk after passing between the wires supporting the pendulum has its other end attached to the cap at the top at a point to the S. of the centre of the cap. Thus the silk is slightly inclined to the plane through the wires. The arrangement for varying the length of the disturbing pendulum will not be explained in detail, but it may suffice to say that it is produced by a third weight, which we call the 'guide weight,' which may be hauled up or let down in an approximately vertical line. This guide weight determines by its position how much of the upper part of the silk of the disturber shall be cut off, so as not to form a part of the free cord by which the disturbing weight hangs.

The guide weight may be raised or lowered by cords which pass through the cap. If the apparatus were to work properly a given amount of displacement of the guide weight should produce a calculable horizontal thrust on the pendulum. The whole of the arrangements for the disturber could be made outside the copper tube, so that the pendulum was lowered into the tube with the disturber attached thereto.

After the mirror was hung and the mirror-box screwed on, a brass cap was fixed by screws on to the flange at the top of the copper tube. This cap has a tube or chimney attached to it, the top of which rises five inches above the top of the cap or lid from which the pendulum hangs. From this chimney emerges a rod attached to the screw by which the sensitising apparatus is actuated, and also the silk by which the guide weight is raised or depressed.

The copper tube, with its appendages, was then filled with a boiled mixture of filtered water and spirits of wine by means of a small tap in the back of the mirror-box. The mixture was made by taking equal volumes of the two fluids; the boiling to which it was subjected will of course have somewhat disturbed the proportions. Poiseuille has shown [1] that a mixture of spirits and water has much greater viscosity than either pure spirits or pure water. When the mixture is by weight in the proportion of about seven of water to nine of spirits, the viscosity is nearly three times as great as that of pure spirits or of pure water. As the specific gravity of spirits is about ·8, it follows that the mixture is to be made by taking equal volumes of the two fluids. It is on account of this remarkable fact that we chose this mixture in which to suspend the pendulum, and we observed that the unsteadiness of the mirror was markedly less than when the fluid used was simply water.

The level of the fluid stood in our tubular support quite up to the top of the chimney, and thus the highest point of the pendulum itself was 5 inches below the surface.

The tub was then let down over the instrument, and the weights hooked on to its edge. The plate-glass window in the tub stood on the S. opposite to the mirror-box. The tub was filled with water up to nearly the top of the chimney, and the ditch round the stone basement was also ultimately filled with water. The whole instrument thus stood immersed from top to bottom in water.

Even before the tub was filled we thought that we noticed a diminution of unsteadiness in the image of a slit reflected from the mirror. The filling of the tub exercised quite a striking effect in the increase of steadiness, and the water in the ditch again operated favourably.

We met with much difficulty at first in preventing serious leakage of the tub, and as it is still not absolutely watertight, we have arranged a water-pipe to drip about once a minute into the tub. A small overflow pipe from the tub to the ditch allows a very slow dripping to go into the ditch, and thus both vessels are kept full to a constant level. We had to take this course because we found that a rise of the water in the ditch through half an inch produced a deflection of the pendulum. The ditch, it must be remembered, was a little broader on the S. side than elsewhere.

In May, 1881, we took a series of observations with the light, slit and scale. The scale was about 7 feet from the tub, and in order to read it we found it convenient to kneel behind the scale on the ground. I was one day watching the light for nearly ten minutes, and being tired with kneeling on the pavement I supported part of my weight on my hands a few inches in front of the scale. The place where my hands came was on the bare earth from which one of the paving stones had been removed. I was surprised to find quite a large change in the reading. After

[1] *Poggendorf's Annalen*, 1843, vol. 58, p. 437.

several trials I found that the pressure of a few pounds with one hand only was quite sufficient to produce an effect.

It must be remembered that this is not a case of a small pressure delivered on the bare earth at say 7 feet distance, but it is the difference of effect produced by this pressure at 7 feet and 8 feet; for of course the change only consisted in the change of distribution in the weight of a small portion of my body.

We have, however, since shown that even this degree of sensitiveness may be exceeded.

We had thought all along that it would ultimately be necessary to take our observations from outside the room, but this observation impressed it on us more than ever; for it would be impossible for an observer always to stand in exactly the same position for taking readings, and my brother and I could not take a set of readings together on account of the difference between our weights.

In making preliminary arrangements for reading from outside the room we found the most convenient way of bringing the reflected image into the field of view of the telescope was by shifting a weight about the room. My brother stood in the room and changed his position until the image was in the field of view, and afterwards placed a heavy weight where he had been standing; after he had left the room the image was in the field of view.

On the S.W. wall of the room there is a trap-door or window which opens into another room, and we determined to read from this.

In order to read with a telescope the light has to undergo two reflections and twelve refractions, besides those in the telescope; it has also to pass twice through layers of water and of the fluid mixture. In consequence of the loss of light we found it impossible to read the image of an illuminated scale, and we had to make the scale self-luminous.

On the pavement to the S. of the instrument is placed a flat board on to which are fixed a pair of rails; a carriage with three legs slides on these rails, and can be driven to and fro by a screw of ten threads to the inch. Backlash in the nut which drives the carriage is avoided by means of a spiral spring. A small gas-flame is attached to the carriage; in front of it is a piece of red glass, the vertical edge of which is very distinctly visible in the telescope after reflection from the mirror. The red glass was introduced to avoid prismatic effects, which had been troublesome before. The edge of the glass was found to be a more convenient object than a line which had been engraved on the glass as a fiducial mark.

The gas-flame is caused to traverse by pulleys driven by cords. The cords come to the observing window, and can be worked from there. A second telescope is erected at the window, for reading certain scales attached to the traversing gear of the carriage, and we find that we can read the position of the gas-flame to within a tenth of an inch, or even less, with certainty.

From the gas the ray of light enters the tub and mirror-box, is reflected by the mirror, and emerges by the same route; it then meets a looking-glass which reflects it nearly at right angles and a little upwards, and finally enters the object-glass of the reading telescope, fixed to the sill of the observing window.

When the carriage is at the right part of the scale the edge of the red glass coincides with the cross wire of the reading telescope, and the reading is taken by means of the scale telescope.

Arrangements had also to be made for working the sensitiser, centraliser, and disturber from outside the room.

A scaffolding was erected over the tub, but free of contact therewith, and this supported a system of worm-wheels, tangent screws, and pulleys by which the three requisite movements could be given. The junctures with the sensitising and centralising rods were purposely made loose, because it was found at first that a slight shake to the scaffolding disturbed the pendulum.

The pulleys on the scaffolding are driven by cords which pass to the observing window.

On the window-sill we now have two telescopes, four pulleys, an arrangement, with a scale attached, for raising and depressing the guide weight, and a gas tap for governing the flame in the room.

After the arrangements which have been described were completed we sensitised the instrument from outside the room. The arrangements worked so admirably that we could produce a quite extraordinary degree of sensitiveness by the alternate working of the sensitising and centralising wheels, without ever causing the image of the lamp to disappear from the field of view. This is a great improvement on the old arrangement with the stone gallows.

We now found that if one of us was in the room and stood at about 16 feet to the S. of the instrument with his feet about a foot apart, and slowly shifted his weight from one foot to the other, then a distinct change was produced in the position of the mirror. This is the most remarkable proof of sensitiveness which we have yet seen, for the instrument can detect the difference between the distortion of the soil caused by a weight of 140 lbs. placed at 16 feet and at 17 feet. We have not as yet taken any great pains to make the instrument as sensitive as possible, and we have little doubt but that we might exceed the present degree of delicacy, if it were desirable to do so.

The sensitiveness now attained is, we think, only apparently greater than it was with the stone gallows, and depends on the improved optical arrangements, and the increase of steadiness due to the elimination of changes of temperature in the support.

From July 21 to July 25 we took a series of readings. There was evidence of a distinct diurnal period with a maximum about noon, when the pendulum stood furthest northwards; in the experiment with the stone gallows in 1880 the maximum northern excursion took place between 5 and 7 P.M.

The path of the pendulum was interrupted by many minor zigzags, and it would sometimes reverse its motion for nearly an hour together. During the first four days the mean position of the pendulum travelled southward, and the image went off the scale three times, so that we had to recentralise it. In the night between the 24th and 25th it took an abrupt turn northward, and the reading was found in the morning of the 25th at nearly the opposite end of the scale.

On the 25th the dance of the image was greater than we had seen it at any time with the new instrument, so that we went into the room to see whether the water had fallen in the tub and had left the top of the copper tube exposed; for on a previous occasion this had appeared to produce much unsteadiness. There was, however, no change in the state of affairs. A few days later the image was quite remarkable for its steadiness.

On July 25, and again on the 27th, we tried a series of observations with the disturber, in order to determine the absolute value of the scale.

The guide weight being at a known altitude in the copper tube we took a series of six readings at intervals of a minute, and then shifting the guide weight to another known altitude, took six more in a similar manner; and so on backwards and forwards for an hour.

The first movement of the guide weight produced a considerable disturbance of an irregular character, and the first set of readings were rejected. Afterwards there was more or less concordance between the results, but it was to be noticed there was a systematic difference between the change from 'up' to 'down' and 'down' to 'up.' This may perhaps be attributed to friction between certain parts of the apparatus. We believe that on another occasion we might erect the disturber under much more favourable conditions, but we do not feel sure that it could ever be made to operate very satisfactorily.

The series of readings before and after the change of the guide weight were taken in order to determine the path of the pendulum at the critical moment; but the behaviour of the pendulum is often so irregular, even within a few minutes, that the discrepancy between the several results and the apparent systematic error may be largely due to unknown changes, which took place during the minute which necessarily elapsed between the last of one set of readings and the first of the next. The image took up its new position deliberately, and it was necessary to wait until it had come to its normal position.

Between the first and second set of observations with the disturber, it had been necessary to enter the room and to recentralise the image. We do not know whether something may not have disturbed the degree of sensitiveness, but at any rate the results of the two sets of observations are very discordant.[1]

The first set showed that one inch of movement of the gas-flame, which formed the scale, corresponds with $\frac{1}{13}$th of a second of arc of change of horizon; the second gave $\frac{1}{5}$th of a second to the inch.

As we can see a twentieth of an inch in the scale, it follows that a change of horizon of about $0''\cdot005$ should be distinctly visible. In this case the point of the pendulum moves through $\frac{1}{40000}$th of a millimeter. At present we do not think that the disturber gives more than the order of the changes of horizon which we note, but our estimate receives a general confirmation from another circumstance.

From the delicacy of the gearing connected with the back-leg, we estimate that it is by no means difficult to raise the back-leg by a millionth of an inch. The looseness in the gearing was purposely kept so great that it requires a turn or two of the external pulley on the window-sill before the backlash is absorbed, but after this a very small fraction of a turn is sufficient to move the image in the field.

We are now inclined to look to this process with the back-leg to enable us to determine the actual value of our scale, but this will require a certain amount of new apparatus, which we have not yet had time to arrange. In erecting the instrument we omitted to take certain measurements which it now appears will be necessary for the use of the back-leg as a means of determining the absolute value of our scale, but we know these measurements approximately from the working drawings of the

[1] See, however, the postscript at the end of this part.

instrument. Now it appears that one complete revolution of a certain tangent-screw by which the back-leg is raised should tilt the pendulum-stand through almost exactly half a second of arc, and therefore this should produce a relative displacement of the pendulum of the same amount. We have no doubt but that a tenth of the turn of the tangent-screw produces quite a large deflection of the image, and probably a hundredth of a turn would produce a sensible deflection. Therefore, from mere consideration of the effect of the back-leg we do not doubt but that a deflection of the pendulum through a $\frac{1}{200}$th of a second of arc is distinctly visible. This affords a kind of confirmation of the somewhat unsatisfactory deductions which we draw from the operation of the disturber.

Postscript.—The account of our more recent experiments was written during an absence from Cambridge from July 29 to August 9. In this period the gradual southerly progression of the pendulum-bob, which was observed up to July 28, seems to have continued; for on August 9 the pendulum was much too far S. to permit the image of the gas-flame to come into the field of view of the telescope. On August 9 the image was recentralised, and on the 9th and 10th the southerly change continued; on the 11th, however, a reversal northwards again occurred. During these days the unsteadiness of the image was much greater than we have seen it at any time with the new instrument. There was some heavy rain and a good deal of wind at that time. We intend to arrange a scale for giving a numerical value to the degree of unsteadiness, but at present it is merely a matter of judgment.

It seems possible that earthquakes were the cause of unsteadiness on August 9, 10, and 11, and we shall no doubt hear whether any earthquakes have taken place on those days.

After August 11 we were both again absent from Cambridge. On August 16 my brother returned, and found that the southerly progression of the pendulum-bob had reasserted itself, so that the image was again far out of the field of view. After recentralising he found the image to be unusually steady.

This appeared a good opportunity of trying the effect of purely local tremors.

One observer therefore went into the room and, standing near the instrument, delivered some smart blows on the brickwork coping round the ditch, the stone pavement, the tub, and the large stone basement underneath the water. Little or no effect was produced by this. Very small movements of the body, such as leaning forward while sitting in a chair, or a shift of part of the weight from heels to toes, produced a sensible deflection, and it was not very easy for the experimenter to avoid this kind of change whilst delivering the blows. To show the sensitiveness of the instrument to steady pressure we may mention that a pressure of three fingers on the brick coping of the ditch produces a marked deflection.

On August 17 I returned to Cambridge, and noted, with my brother, that the image had never been nearly so steady before. The abnormal steadiness continued on the 18th. There was much rain during those days.

On the afternoon of the 19th there was a high wind, and although the abnormal steadiness had ceased, still the agitation of the image was rather less than we usually observe it.

The image being so steady on the 17th, we thought that a good opportunity was afforded for testing the disturber. At 6.15 P.M. of that day we began the readings. The changes from 'up' to 'down' were made as quickly as we could, and in a quarter of an hour we secured five readings when the guide weight was 'up,' and four when it was 'down.'

When a curve was drawn, with the time as abscissa, and the readings as ordinates, through the 'up's,' and similarly through the 'down's,' the curves presented similar features. This seems to show that movement of the disturber does not cause irregularities or changes, except such as it is designed to produce.

The displacement of the guide weight was through 5 c.m. on each occasion.

The four changes from 'up' to 'down' showed that an inch of scale corresponded with 0″·0897, with a mean error of 0″·0021; the four from 'down' to 'up' gave 0″·0909 to the inch, with a mean error of 0″·0042. Thus the systematic error on the previous occasions was probably only apparent.

Including all the eight changes together, we find that the value of an inch is 0″·0903 with a mean error of 0″·0030.

A change in the scale reading amounting to a tenth of an inch is visible without any doubt, and even less is probably visible. Now it will give an idea of the delicacy of the instrument when we say that a tenth of an inch of our scale corresponds to a change of horizon[1] through an angle equal to that subtended by an inch at 384 miles.

II. *On the work of previous observers.*

In the following section we propose to give an account of the various experiments which have been made in order to detect small variations of horizon, as far as they are known to us; but it is probable that other papers of a similar kind may have escaped our notice.

In a report of this kind it is useful to have references collected together, and therefore, besides giving an account of the papers which we have consulted, we shall requote the references contained in these papers.

In Poggendorf's 'Annalen' for 1873 there are papers by Professor F. Zöllner, which had been previously read before the Royal Saxon Society, and which are entitled 'Ueber eine neue Methode zur Messung anziehender und abstossender Kräfte,' vol. 150, p. 131, 'Beschreibung und Anwendung des Horizontalpendels,' vol. 150, p. 134. A part of the second of these papers is translated, and the figure is reproduced in the supplementary number of the 'Philosophical Magazine' for 1872, p. 491, in a paper 'On the Origin of the Earth's Magnetism.'

The horizontal pendulum was independently invented by Professor Zöllner, and, notwithstanding assertions to the contrary, was probably for the first time actually realised by him; it appears, however, that it had been twice invented before. The history of the instrument contains a curious piece of scientific fraud, of which we shall give an account below.

The instrument underwent some modifications under the hands of Professor Zöllner, and the two forms are described in the above papers.

[1] We use the expression 'change of horizon' to denote relative movement of the earth, at the place of observation, and the plumb-line. Such changes may arise either from alteration in the shape of the earth, or from displacement of the plumb-line; our experiments do not determine which of these two really takes place.

The principle employed is as follows:—There is a very stout vertical stand, supported on three legs. At the top and bottom of the vertical shaft are fixed two projections. Attached to each projection is a fine straight steel clock spring; the springs are parallel to the vertical shaft of the stand, the one attached to the lower projection running upwards, and that attached to the upper one running downwards. The springs are of equal length, each being equal to half the distance between their points of attachment on the projections.

The springs terminate in a pair of rings, which stand exactly opposite to one another, so that a rod may be thrust through both.

A glass rod has a heavy weight attached to one end of it, and the other end is thrust through the two rings. The rings are a little separated from one another, and the glass rod stands out horizontally, with its weight at the end, and is supported by the tension of the two springs. It is obvious that if the point of attachment of the upper spring were vertically over that of the lower spring, and if the springs had no torsional elasticity, then the glass rod would be in neutral equilibrium, and would stand equally well in any azimuth.

The springs being thin have but little torsional elasticity, and Professor Zöllner arranges the instrument so that the one support is very nearly over the other. In consequence of this the rod and weight have but a small predilection for one azimuth more than another. The free oscillations of the horizontal pendulum could thus be made extraordinarily slow; and even a complete period of one minute could be easily attained.

A very small horizontal force of course produces a large deflection of the pendulum, and a small deflection of the force of gravitation with reference to the instrument must produce a like result. He considers that by this instrument he could, in the first form of the instrument, detect a displacement of the horizon through $0''\cdot00035$; in the second his estimate is $0''\cdot001$.

The observation was made by means of a mirror attached to the weight, and scale and telescope.

The maximum change of level due to the moon's attraction is at St. Petersburg $0''\cdot0174$, and from the sun $0''\cdot0080$ [C. A. F. Peters, 'Bull. Acad. Imp. St. Pétersbourg,' 1844, vol. 3. No. 14]; and thus the instrument was amply sensitive enough to detect the lunar and solar disturbances of gravity.[1]

Professor Zöllner found, as we have done, that the readings were never the same for two successive instants. The passing of trains on the railway at a mile distant produced oscillations of the equilibrium position.

[1] We are of opinion that M. Zöllner has made a mistake in using at Leipsig Peters' results for St. Petersburg. Besides this he considers the changes of the vertical to be $0''\cdot0174$ on *each* side of a mean position, and thus says the change is $0''\cdot0348$ altogether. Now a rough computation which I have made for Cambridge shows that the maximum meridional horizontal component of gravitation, as due to lunar attraction, is $4\cdot12 \times 10^{-8}$ of pure gravity. This force will produce a deflection of the plumb-line of $0''\cdot0085$, and the total amplitude of meridional oscillation will be $0''\cdot0170$. The maximum deflection of the plumb line occurs when the moon's hour-angle is $\pm 45°$ and $\pm 135°$ at the place of observation. The change at Cambridge when the moon is S.E. and N.W. is $0''\cdot0216$. The deflection of the plumb line varies as the cosine of the latitude, and is therefore greater at Cambridge than at St. Petersburg. Multiplying $\cdot0216$ by sec $51°43'$ cos $60°$ we get $\cdot0174$, and thus my calculation agrees with Peters'.

He seems to have failed to detect the laws governing the longer and wider oscillations performed. Notwithstanding that he took a number of precautions against the effects of changes of temperature, he remarks that 'the external circumstances under which the above experiments were carried out must be characterised as extremely unfavourable for this object (measuring the lunar attraction), so that the sensitiveness might be much increased in pits in the ground, provided the reaction of the glowing molten interior against the solid crust do not generate inequalities of the same order.'

Further on he says that if the displacements of the pendulum should be found not to agree in phase with the theoretical phase as given by the sun's position, then it might be concluded that gravitation must take a finite time to come from the sun.

It appears to me that such a result would afford strong grounds for presuming the existence of frictional tides in the solid earth, and that Professor Zöllner's conclusion would be quite unjustifiable.

Earlier in the paper he states that he preferred to construct his instrument on a large scale, in order to avoid the disturbing effects of convection currents. We cannot but think, from our own experience, that by this course Professor Zöllner lost more than he gained, for the larger the instrument the more it would necessarily be exposed in its various parts to regions of different temperature, and we have found that the warping of supports by inequalities of temperature is a most serious cause of disturbance.

The instrument of which we have given a short account appears to us very interesting from its ingenuity, and the account of the attempts to use it are well worthy of attention, but we cannot think that it can ever be made to give such good results as those which may perhaps be attained by our plan or by others. The variation in the torsional elasticity of the suspending springs, due to changes of temperature, would seem likely to produce serious variations in the value of the displacements of the pendulum, and it does not seem easy to suspend such an instrument in fluid in such a manner as to kill out the effects of purely local tremors.

Moreover, the whole instrument is kept permanently in a condition of great stress, and one would be inclined to suppose that the vertical stand would be slightly warped by the variation of direction in which the tensions of the springs are applied, when the pendulum bob varies its position.

In a further paper in the same volume, p. 140, 'Zur Geschichte des Horizontalpendels,' Zöllner gives the priority of invention to M. Perrot, who had described a similar instrument on March 31, 1862, ('Comptes Rendus,' vol. 54, p. 728), but as far as he knows M. Perrot did not actually construct it.

He also quotes an account of an 'Astronomische Pendelwage,' by Lorenz Hengler, published in 1832, in vol. 43 of 'Dingler's Polytechn. Journ.,' pp. 81–92. In this paper it appears that Hengler gives the most astonishing and vague accounts of the manner in which he detected the lunar attraction with a horizontal pendulum, the points of support being the ceiling and floor of a room 16 feet high. The terrestrial rotation was also detected with a still more marvellous instrument.

Zöllner obviously discredits these experiments, but hesitates to characterise them, as they deserve, as mere fraud and invention.

The university authorities at Munich state that in the years 1830–1 there was a candidate in philosophy and theology named Lorenz Hengler, of Reichenhofen, 'der weder früher noch später zu finden ist.'

At p. 150 of the same volume Professor Šafařik contributes a 'Beitrag zur Geschichte des Horizontalpendels.' He says that the instrument takes its origin from Professor Gruithuisen, of Munich, whose name has 'keinen guten Klang' in the exact sciences.

This strange person, amongst other eccentricities, proposed to dig a hole quite through the earth, and proposes a catachthonic observatory. Gruithuisen says, in his 'Neuen Analekten für Erd- und Himmelskunde' (Munich, 1832), vol. 1, part i.: 'I believe that the oscillating-balance (Schwung-wage) of a pupil of mine (named Hengeller), when constructed on a large scale, will do the best service.'

Some of the most interesting observations which have been made are those of M. d'Abbadie. He gave an account of his experiments in a paper, entitled 'Études sur la verticale,' 'Association Française pour l'avancement des Sciences, Congrès de Bordeaux, 1872,' p. 159. As this work is not very easily accessible to English readers, and as the paper itself has much interest, we give a somewhat full abstract of it. He has also published two short notes with reference to M. Plantamour's observations (noticed below), in vol. 86, p. 1528 (1878), and vol. 89, p. 1016 (1879), of the 'Comptes Rendus.' We shall incorporate the substance of his remarks in these notes in our account of the original paper.

When at Olinda, in Brazil, in 1837, M. d'Abbadie noticed the variations of a delicate level which took place from day to day. At the end of the two months of his stay there the changes in the E. and W. azimuth had compensated themselves, and the level was in the same condition as at first; but the change in the meridian was still progressing when he had to leave.

In 1842, at Gondar, in Ethiopia, and at Saqa, he noticed a similar thing. In 1852 he gave an account to the French Academy ('Comptes Rendus,' May, p. 712) of these observations, as well as of others, by means of levels, which were carried out in a cellar in the old castle of Audaux, Basses Pyrénées.

Leverrier, he says, speaks of sudden changes taking place in the level of astronomical instruments, apparently without cause. Airy has proved that the azimuth of an instrument may change, and Hough notes, in America, capricious changes of the Nadir.

Henry has collected a series of levellings and azimuths observed at Greenwich during ten years, and during eight of the same years at Cambridge ('Monthly Notices, R.A.S.,' vol. 8, p. 134). The results with respect to these two places present a general agreement, and show that from March to September the western Y of the transit instrument falls through $2''\cdot5$, whilst it deviates at the same time $2''$ towards the north. Ellis has made a comparison of curves applying to Greenwich, during eight years, for level and azimuth. He shows that there is a general correspondence with the curves of the external temperature ('Memoirs of the R. Ast. Soc.,' vol. 29, pp. 45–57).

In the later papers M. d'Abbadie says that M. Bouquet de la Grye has observed similar disturbances of the vertical at Campbell Island, lat. 52° 34′ S.. M. Bouquet used a heavy pendulum governing a vertical lever, by which the angle was multiplied.[1] He found that the

[1] I do not find a reference to M. Bouquet in the R.S. Catalogue of scientific papers. It appears from what M. d'Abbadie says that certain observations have

great breakers on the shore at a distance of two miles caused a deviation of the vertical of 1″·1. On one occasion the vertical seems to have varied through 3″·2 in 3¼ hours.

M. d'Abbadie also quotes Elkin, Yvon Villarceau, and Airy as having found, from astronomical observations, notable variations in latitude, amounting to from 7″ to 8″.

As M. d'Abbadie did not consider levels to afford a satisfactory method of observation of the presumed changes of horizon, he determined to proceed in a different manner.

The site of his experiments was Abbadia, in Subernoa, near Hendaye. The Atlantic was 400 meters distant, and the sea level 62 meters below the place of observation. The subsoil was loamy rock (*roche marneuse*), belonging to cretaceous deposits of the South of France. Notwithstanding the steep slope of the soil, water was found at about 5 meters below the surface.

In this situation he had built, in 1863, a concrete cone, of which the external slope was one in ten (une inclinaison d'une dixième). The concrete cone is truncated, and the flat surface at the top is 2 meters in diameter. It is pierced down the centre by a vertical hole or well 1 meter in diameter. This well extends to within half a meter of the top, at which point the concrete closes in, leaving only a hole of 12 centimeters up to the flat upper surface.

From the top of the concrete down to the rock is 8 meters, and the well is continued into the rock to a further depth of 2 meters: thus from top to bottom is 10 meters.

A tunnel is made to the bottom of the well in order to drain away the water, and access of the observer to the bottom is permitted by means of an underground staircase. Access can also be obtained to a point halfway between the top and bottom by means of a hole through the concrete. At this point there is a diaphragm across the well, pierced by a hole 21 centimeters in diameter. The diaphragm seems to have been originally made in order to support a lens, but the mode of observation was afterwards changed. The diaphragm is still useful, however, for allowing the observer to stand there and sweep away cobwebs.

The cone is enclosed in an external building, from the roof of which, as I understand, there hangs a platform on which the observer may stand without touching the cone; and the two staircases leading up to the top are also isolated.[1]

On the hole through the top of the cone is riveted a disk of brass pierced through its centre by a circular hole 21 mm. in diameter. The hole in the disk is traversed across two perpendicular diameters by fine platinum wires; at first there were only two wires, but afterwards there were four, which were arranged so as to present the outline of a right-angled cross. The parallel wires were very close together, so that the four wires enclosed in the centre a very small square space.

At the bottom of the well is put a pool of mercury. The mercury was at first in an iron basin, but the agitation of the mercury was found sometimes to be so great that no reflection was visible for an hour to-

been made with pendulums in Italy, but that it does not distinctly appear that the variations of level are simultaneous over wide areas. No reference is given as to the observers.

[1] This passage appears to me a little obscure, and I cannot quite understand the arrangement.

gether. At the suggestion of Leverrier the iron basin was replaced by a shallow wooden tray with a corrugated bottom, and a good reflection was then generally obtainable. Immediately over the mercury pool there stood a lens of 10 c.m. diameter and 10 meters focal length, and over the brass disk there stood a microscope with moveable micrometer wires in the eyepiece, and a position circle. The platinum wires were illuminated, and on looking through the microscope the observer saw the wires both directly and by reflection. The observations were taken by measuring the azimuth and displacement of the image of the central square relatively to the real square enclosed by the wires.

One division of the micrometer screw indicated a displacement of vertical of $0''\cdot03$, so that the observations were susceptible of considerable refinement.

The whole of the masonry was finished in 1863, and M. d'Abbadie then allowed the structure five years to settle before he began taking observations. The arrangements for observing above described were made in 1868 and 1869.

In the course of a year he secured 2,000 observations, and the results appear to be very strange and capricious.

Throughout March, 1869, the perturbations of the mercury were so incessant, that observations (taken at that time with the iron basin) were nearly impossible; on the 29th he waited nearly an hour in vain in trying to catch the image of the wires. Two days later the mercury was perfectly tranquil. On April 6 it was much agitated, although the air and sea were calm. A tranquil surface was a rare exception.

In 1870 the corrugated trough was substituted for the iron basin; and M. d'Abbadie says :—

'Cependant, ni le fond inégal du bain rainé ni sa forme ne m'ont empêché d'observer, ce que j'appelle des *ombres fuyantes.* Ce sont des bandes sombres et parallèles qui traversent le champ du microscope avec plus ou moins de vitesse, et qu'on explique en attribuant au mercure des ondes très ténues, causées par une oscillation du sol dans un seul sens. Le plus souvent ces *ombres* semblent courir du S.E. au N.O., approximativement selon l'axe de la chaîne des Pyrénées; mais je les ai observées, le 15 Mars 1872, allant vers le S.O. À cette époque le mercure était, depuis le 29 février, dans une agitation continuelle, comme mon aide l'avait constaté en 1869, aussi dans le mois de Mars.'[1]

He observed also, from time to time, certain oscillations of the mercury too rapid to be counted, which he calls 'tremoussements.' There were also sudden jumpings of the image from one point to another, or 'frétillements,' indicating a sudden change of vertical through $0''\cdot49$ to $0''\cdot65$.

He observed many microscopic earthquakes, and in some cases the image was carried quite out of the field of view.

He also detected the difference of vertical according to the state of the tide in the neighbouring sea; but the change of level due to this cause was often masked by others occurring contemporaneously.

From observations during the years 1867 to 1872 (with the exception of 1870) he finds that in every year but one the plumb-line deviated northwards during the latter months of the year, but in 1872 it deviated to the south.

[1] M. d'Abbadie writes to me that this phenomenon was ultimately found to result from air-currents (Nov. 5, 1881).

He does not give any theoretical views as to the causes of these phenomena, but remarks that his observations tend to prove that the causes of change are sometimes neither astronomical nor thermometrical.

The most sudden change which he noted was on October 27, 1872, when the vertical changed by 2″·4 in six hours and a quarter. Between January 30 and March 26 of the same year the plumb-line deviated 4″·5 towards the south.

We now come to the valuable observations of M. Plantamour, which we believe are still being prosecuted by him. His papers are 'Sur le déplacement de la bulle des niveaux à bulle d'air,' 'Comptes Rendus,' June 24, 1878, vol. 86, p. 1522, and 'Des mouvements périodiques du sol accusés par des niveaux à bulle d'air,' 'Comptes Rendus,' December 1, 1879, vol. 89, p. 937.

The observations were made at Sécheron, near Geneva, at first at the Observatory, and afterwards at M. Plantamour's house. After some preliminary observations he obtained a very sensitive level and laid it on the concrete floor of a room in which the variations of temperature were very small. The azimuth of the level was E. and W., and the observations were made every hour from 9 A.M. until midnight. Figures are given of the displacement of the bubble during April 24, 25, and 26, 1878. The results indicate a diurnal oscillation of level, the E. end of the level being highest towards 5.30 P.M.; the amplitudes of the oscillations were 8″·4, 11″·2, 15″·75 during these three days. It also appeared that there was a gradual rising of the mean diurnal position of the E. end during the same time.

The level was then transported to a cellar in M. Plantamour's house, when the temperature only varied by half a degree centigrade. The bubble of the level often ran quite up to one end. A new and larger level was obtained, together with the great 'chevalet de fer,' which is used by the manufacturers in testing levels. Both levels were placed E. and W., at about two meters apart. During May 3 and 4, 1878, the bubble travelled eastward without much return, and it is interesting to learn that simultaneous observations by M. Turretini, at the Level Factory, three kilometers distant, at Plainpalais, showed a similar change.

Between May 3 and 6 the level actually changed through 17″. Up to the 19th the level still showed the eastward change.

M. Plantamour remarks that the eastern pier of a transit instrument is known to rise during a part of the year, but not by an amount comparable with that observed by him, and that the diurnal variations are unknown.

After further observations of a similar kind one of the levels was arranged in the N. and S. azimuth.

The same sort of diurnal oscillations, although more irregular, were observed, but the hours of maximum were not the same in the two levels. During the four days May 24 to 28 the maximum rising of the north generally took place about noon. This is exactly the converse of what we have recently observed.

In the second paper he remarks:

'Dans le sens du méridien, les mouvements diurnes sont très rares irréguliers et toujours très faibles, le niveau en accuse parfois, quand il n'y en a point de l'est à l'ouest, et inversement, quand ces derniers sont très prononcés, on n'en aperçoit que très rarement du sud au nord.'

In our experiment of March 15 to 18, 1880, we found that the pendulum stood furthest north about 6 P.M., so that at that time the S. was most elevated; and in the short series of observations during the present summer the maximum elevation of the S. took place about noon.

On October 1, 1878, M. Plantamour began a new series of observations, which lasted until September 30, 1879. The levels were arranged in the two azimuths as before, and the observations were taken five times a day, namely, at 9 A.M., noon, 3, 6, and 9 P.M. The mean of these five readings he takes as the diurnal value.

During October and November the eastern end of the level fell, which is exactly the converse of what happened during the spring of the same year; he concludes that the eastern end falls when the external temperature falls.

When a curve of the external temperature was placed parallel with that for the level, it appeared that there was a parallelism between the two, but the curve for the level lagged behind that for temperature by a period of from one to four days.

This parallelism was maintained until the end of June, 1879, when it became disturbed. From then until the beginning of September the E. rose, but in a much greater proportion than the rise of mean temperature. It must be noted that July was a cold and wet month.

Although the external temperature began to fall on August 5, the E. end continued to rise until September 8. This he attributes to an accumulation of heat in the soil. The total amplitude of the annual oscillation from E. to W. amounted to 28″·08.

There was also a diurnal oscillation in this azimuth which amounted to 3″·2 on September 5. The east end appeared to be highest between 6 and 7.45 P.M., and lowest at the similar hour in the morning.[1]

The meridional oscillations were much smaller, the total annual amplitude being only 4″·89. From December 23, 1878, until the end of April, 1879, there was a correspondence between the external temperature curve and that for N. and S. level. We have already quoted the remark on the diurnal meridional oscillations.

M. Plantamour tells us that in 1856 Admiral Mouchez detected no movement of the soil by means of the levels attached to astronomical instruments. On the other hand, M. Hirsch established, by several years of observation at Neuchâtel, that there was an annual oscillation of a transit instrument from E. to W., with an amplitude of 23″, and an azimuthal oscillation of 75″. Similar observations with the transit instrument were made at the observatory at Berne in the summer of 1879.

It is to be regretted that M. Plantamour does not give us more information concerning the manner in which the iron support for the levels was protected from small changes of temperature, nor with regard to the effect of the observer's weight on the floor of the room. We have concluded that both these sources of disturbance should be carefully eliminated.

[1] It seems that M. Plantamour sent a figure to the French Academy with the paper, but no figure is given. This figure would doubtless have explained the meaning of some passages which are somewhat obscure. Thus he speaks of the *minimum* occurring between 6 and 7.45, but it is not clear whether minimum means E. highest or E. lowest. I interpret the passage as above, because this was the state of things in the observations recorded in the first of the two papers. There is a similar difficulty about the meridional oscillations.

Some interesting observations were made at Pulkova on a subject cognate to that on which we are writing. M. Magnus Nyrén contributed, on February 28, 1878, an interesting note to the Imperial Academy of St. Petersburg, entitled 'Erderschütterung beobachtet an einem feinem Niveau 1877 Mai 10.'[1] On May 10 (April 28), 1877, at 4.16 A.M., a striking disturbance of the level on the axis of the transit was observed by M. Nyrén in the observatory at Pulkova. The oscillations were watched by him for three minutes; their complete period was about 20 seconds, and their amplitude between 1″·5 and 2″. At 4.35 A.M. there was no longer any disturbance. He draws attention to the fact that it afterwards appeared that one hour and fourteen minutes earlier there had been a great earthquake at Iquique. The distance from Iquique to Pulkova is 10,600 kilometers in a straight line, and 12,540 kilometers along the arc of a great circle. He does not positively connect the two phenomena together; but he observes that if the wave came through the earth from Iquique to Pulkova it must have travelled at the rate of about 2·4 kilometers per second. This is the speed of transmission through platinum or silver.

M. Nyrén thinks the wave-motion could not have been so regular as it was, if the transmission had been through the solid, and suggests that the transmission was through the fluid interior of the earth.

It appears to us that this argument is hardly sound, and that it would be more just to conclude that the interior of the earth was a sensibly perfectly elastic solid; because oscillations in molten rock would surely be more quickly killed out by internal friction than those in a solid. However, M. Nyrén does not lay much stress on this argument. He also draws attention to the fact that on September 20 (8), 1867, M. Wagner observed at Pulkova an oscillation of the level, with an amplitude of 3″, and that seven minutes before the disturbance there had been an earthquake at Malta. On April 4 (March 23), 1868, M. Gromadzki observed an agitation of the level, and it was afterwards found that there had been an earthquake in Turkestan five minutes before.

Similar observations of disturbances had been made twice before, once by M. Wagner and once by M. Romberg; but they had not been connected with any earthquakes—at least with certainty.

Dr. C. W. Siemens has invented an instrument of extraordinary delicacy, which he calls an 'Attraction-meter.' An account of the instrument is given in an addendum to his paper 'On determining the depth of the sea without the use of the sounding-line' ('Phil. Trans.,' 1876, p. 659). We shall not give any account of this instrument, because Dr. Siemens is a member of our committee, and will doubtless bring any observations he may make with it before the British Association at some future time.

III. *Remarks on the present state of the subject.*

Although our experiments are not yet concluded, it may be well to make a few remarks on the present aspects of the question, and to state shortly our intentions as to future operations.

Our experiments, as far as they go, confirm the results of MM. d'Abbadie and Plantamour, and we think that there can remain little

[1] *Bull. Acad. St. Pét.*, vol. 24, p. 567.

doubt that the surface of the earth is in incessant movement, with oscillations of periods extending from a fraction of a second to a year.

Whether it be a purely superficial phenomenon or not, this consideration should be of importance to astronomical observers, for their instruments are necessarily placed at the surface of the earth. M. Plantamour and others have shown that there is an intimate connection between the changes of level and those of the temperature of the air; whence it follows that the principal part of the changes must be superficial. On the other hand, M. d'Abbadie has shown that it is impossible to explain all the changes by means of changes of temperature. It would be interesting to determine whether changes of a similar kind penetrate to the bottom of mines, and Gruithuisen's suggestion of a catachthonic observatory seems worthy of attention, although he perhaps went rather far in the proposition that the observatory should be ten or fifteen miles below the earth's surface.

It may appear not improbable that the surface of the soil becomes wrinkled all over, when it is swollen by increase of temperature and by rainfall. If this, however, were the case, then we should expect that instruments erected at a short distance apart would show discordant results. M. Plantamour, however, found that, at least during three days, there was a nearly perfect accordance between the behaviour of two sets of levels at three kilometers apart; and during eight years there appeared to be general agreement between the changes of level of the astronomical instruments at Greenwich and Cambridge. It would be a matter of much interest to determine how far this concordance would be maintained if the instrument of observation had been as delicate as that used by M. d'Abbadie or as our pendulum.

M. Plantamour speaks as though it were generally recognised that one pier of a transit circle rises during one part of the year and falls at another.[1] But if this be so throughout Europe, we must suppose that there is a kind of tide in the solid earth, produced by climatic changes; the rise and fall of the central parts of continents must then amount to something considerable in vertical height, and the changes of level on the easterly and westerly coasts of a continent must be exactly opposite to one another. We are not aware that any comparison of this kind has been undertaken. The idea seems of course exceedingly improbable, but we understand it to be alleged that it is the eastern pier of transit instruments in Europe which rises during the warmer part of the year. Now if this be generally true for Europe, which has no easterly coast, it is not easy to see how the change can be brought about except by a swelling of the whole continent.

We suggest that in the future it will be thought necessary to erect at each station a delicate instrument for the continuous observation of changes of level. Perhaps M. d'Abbadie's pool of mercury might be best for the longer inequalities, and something like our pendulum for the shorter ones; or possibly the pendulum when used in a manner which we intend to try might suffice for all the inequalities.

[1] 'Dans l'opération au moyen de laquelle on vérifie l'horizontalité de l'axe d'une lunette méridienne, il parait qu'on remarque bien un léger mouvement d'exhaussement de l'est pendant une partie de l'année, mais il n'est pas aussi considérable que celui qu'accuse mon niveau, et l'on n'a jamais remarqué, que je sache, une oscillation diurne comme celle qu'a indiquée le niveau dans le pavillon.'—*Comptes Rendus*, June 24, 1878, vol. 86, p. 1525.

At present the errors introduced by unknown inequalities of level are probably nearly eliminated by the number of observations taken; but it could not fail to diminish the probable error of each observation, if a correction were applied for this cause of disturbance from hour to hour, or even from minute to minute. If the changes noted by M. Plantamour are not entirely abnormal in amount, such corrections are certainly sufficient to merit attention.

In our first set of experiments we found that stone piers are exceedingly sensitive to changes of temperature and to small stresses. Might it not be worth while to plate the piers of astronomical instruments with copper, and to swathe them with flannel? We are not aware as to the extent to which care is taken as to the drainage of the soil round the piers, or as to the effect of the weight of the observer's body; but we draw attention to the effect produced by the percolation of water round the basement, and to the impossibility we have found of taking our observations in the same room with the instrument.

In connection with this subject we may notice an experiment which was begun 3½ years ago by my brother Horace. The experiment was undertaken in connection with my father's investigation of the geological activity of earthworms, and the object was to determine the rate at which stones are being buried in the ground in consequence of the excavations of worms.

The experiment is going on at Down, in Kent. The soil is stiff red clay, containing many flints lying over the chalk. There are two stout metal rods, one of iron and the other of copper. The ends were sharpened and they were hammered down vertically into the soil of an old grass field, and they are in contact with one another, or nearly so. When they had penetrated 8 feet 6 inches it was found very difficult to force them deeper, and it is probable that the ends are resting on a flint. The ends were then cut off about three inches above the ground.

A stone was obtained like a small grindstone, with a circular hole in the middle. This stone was laid on the ground with the two metal rods appearing through the hole. Three brass V grooves are leaded into the upper surface of the stone, and a moveable tripod-stand with three rounded legs can be placed on the stone, and is, of course, geometrically fixed by the nature of its contact with the V's. An arrangement with a micrometer screw enables the observer to take contact measurements of the position of the upper surface of the stone with regard to the rods. The stone has always continued to fall, but during the first few months the rate of fall was probably influenced by the decaying of the grass underneath it. The general falling of the stone can only be gathered from observations taken at many months apart, for it is found to be in a state of continual vertical oscillation.

The measurements are so delicate that the raising of the stone produced by one or two cans full of water poured on the ground can easily be perceived. Between September 7 and 19, 1880, there was heavy rain, and the stone stood 1·91 mm. higher at the latter date than at the former. The effect of frost and the wet season combined is still more marked, for on January 23, 1881, the stone was 4·12 mm. higher than it had been on September 7, 1880.

The prolonged drought of the present summer has had a great effect, for between May 8 and June 29 the stone sank through 5·79 mm. The opposite effects of drought and frost are well shown by the fact that on

January 23 the stone stood 8·62 mm. higher than on June 29, 1881. The observations are uncorrected for the effect of temperature on the metal rods, but the fact that the readings from the two rods of different metals always agree very closely *inter se*, shows that such a correction would amount to very little.

The changes produced in the height of the stone are, of course, entirely due to superficial causes; but the amounts of the oscillations are certainly surprising, and although the basements of astronomical instruments may be very deep, they cannot entirely escape from similar oscillations.

In his address to the mathematical section at the meeting of the British Association at Glasgow in 1876, Sir William Thomson tells us[1] that Peters, Maxwell, Nyrén, and Newcomb[2] have examined the observations at Pulkova, Greenwich, and Washington, in order to discover whether there is not an inequality in the latitude of the observatories having a period of about 306 days. Such an inequality must exist on account of the motion in that period of the instantaneous axis of rotation of the earth round the axis of maximum moment of inertia. The inequality was detected in the results, but the probable error was very large, and the epochs deduced by the several investigators do not agree *inter se*. It remains, therefore, quite uncertain whether the detection of the inequality is a reality or not. But now we ask whether it is not an essential first step in such an enquiry to make an elaborate investigation by a very delicate instrument of the systematic changes of vertical at each station of observation?

We will next attempt to analyse the merits and demerits of the various methods which have been employed for detecting small changes in the vertical.

The most sensitive instrument is probably the horizontal pendulum of Professor Zöllner, and its refinement might be almost indefinitely increased by the addition of the bifilar suspension of a mirror as a means of exhibiting the displacements of the pendulum-bob. If this were done it might be possible to construct the instrument on a very small scale and yet to retain a very high degree of sensitiveness. We are inclined to think, however, that the variation of the torsional elasticity of the suspending springs under varying temperature presents an objection to the instrument which it would be very difficult to remove. The state of stress under which the instrument is of necessity permanently retained seems likely to be prejudicial.

Next in order of sensitiveness is probably our own pendulum, embodying the suggestion of Sir William Thomson. We are scarcely in a position as yet to feel sure as to its merits, but it certainly seems to be capable of all the requisite refinement. We shall give below the ideas which our experience, up to the present time, suggest as to improvements and future observations.

Although we know none of the details of M. Bouquet de la Grye's pendulum actuating a lever, it may be presumed to be susceptible of considerable delicacy, and it would be likely to possess the enormous

[1] *B. A. Report* for 1876, p. 10. For 'Nysen' read 'Nyrén.'

[2] Peters' paper is in *Bull. St. Pet. Acad.*, 1844, p. 305, and *Ast. Nach.* vol. 22, 1845, p. 71, 103, 119. Nyrén's paper is in *Mém. St. Pet. Acad.* vol. 19, 1873, No. 13. With regard to Maxwell, see Thomson and Tait's *Nat. Phil.* 2nd edit. part 1, vol. 1. An interesting letter from Newcomb is quoted in Sir W. Thomson's address.

advantage of giving an automatic record of its behaviour. On the other hand the lever must introduce a very unfavourable element in the friction between solids.

M. d'Abbadie's method of observation by means of the pool of mercury seems on the whole to be the best which has been employed hitherto. But it has faults which leave ample fields for the use of other instruments. The construction of a well of the requisite depth must necessarily be very expensive, and when the structure is made of a sufficient size to give the required degree of accuracy, it is difficult to ensure the relative immobility of the cross wires and the bottom of the well.

Levels are exceedingly good from the point of view of cheapness and transportability, but the observations must always be open to some doubt on account of the possibility of the sticking of the bubble from the effects of capillarity. The justice of this criticism is confirmed by the fact that M. Plantamour found that two levels only two meters apart did not give perfectly accordant results. Levels are moreover, perhaps, scarcely sensitive enough for an examination of the smaller oscillations of level. Dr. Siemens' form of level possesses ample sensibility, but is probably open to the same objections on the score of capillarity.

In the case of our own experiments we think that the immersion of the whole instrument in water from top to bottom has proved an excellent precaution against the effects of change of temperature, and our experience leads us to think that much of the agitation of the pendulum in the earlier set of experiments was due to small variations of temperature against which we are now guarded.

The sensitiveness of the instrument leaves nothing to be desired, and were such a thing as a firm foundation attainable, we could measure the horizontal component of the lunar attraction to a considerable degree of accuracy. We believe that this is the first instrument in which the viscosity of fluids has been used as a means of eliminating the effects of local tremors. In this respect we have been successful, for we find that jumping or stamping in the room itself produces no agitation of the pendulum, or at least none of which we can feel quite sure. We are inclined to try the effect of fluids of greater viscosity, such as glycerine, syrup of sugar, or paraffin oil. But along with such fluids we shall almost inevitably introduce air-bubbles, which it may be hard to get rid of. If a fluid of great viscosity were used, we should then only observe the oscillations of level of periods extending over perhaps a quarter to half a minute. The oscillations of shorter periods are, however, so inextricably mixed up with those produced by carriages and railway trains, that nothing would be lost by this.

In connection with this point Mr. Christie writes to me, that 'In the old times of Greenwich Fair, some twenty years ago, when crowds of people used to run down the hill, I find the observers could not take reflection observations for two or three hours after the crowd had been turned out. . . . . We do not have anything like such crowds now, even on Bank holidays, and I have not heard lately of any interference with the observations.' If the observers attributed the agitation of the mercury to the true cause, the elasticity of the soil must be far more perfect than is generally supposed. It would be surprising to find a mass of glass or steel continuing to vibrate for as long as two hours after the disturbance was removed. May it not be suspected that times of agitation, such as those noted by M. d'Abbadie, happened to coincide on two or three occasions with Greenwich Fair?

As the sensitiveness of our present instrument is very great, although the sensitising process has never been pushed as far as possible, we think that it will be advantageous to construct an instrument on half, or even less than half, the present scale. The heavy weights which we now have to employ will thus be reduced to one-eighth of the present amount. The erection of the instrument may thus be made an easy matter, and an easily portable and inexpensive instrument may be obtained.

Our present form of instrument has several serious flaws. The image is continually travelling off the scale, the gearing both internal and external to the room for observing is necessarily complex and troublesome to erect, and lastly we have not yet succeeded in an accurate determination of the value of the scale.

We are in hopes of being able to overcome all these objections. We propose to have a fixed light, which may be cast into the room from the outside. This will free us from the obviously objectionable plan of having a gas-flame in the room, and at the same time will abolish the gearing for traversing the lamp on the scale. We should then abolish the disturbing pendulum and thus greatly simplify the instrument. The readings would be taken by the elevation or depression of the back-leg, until the image of the fixed light was brought to the cross wire of the observing telescope.

The ease with which the image may be governed with our present arrangements leads us to be hopeful of the proposed plan. The use of the back-leg will, of course, give all the displacements in absolute measure.

The only gearings which it will be necessary to bring outside the room will be those for sensitising and for working the back-leg. The sensitising gearing when once in order will not have to be touched again.

The objections to this plan are, that it is necessary to bring one of the supports of the instrument under very slight stresses, and that it will not be possible to take readings at small intervals of time, especially if a more viscous fluid be used.

Our intention is to proceed with our observations with the present instrument for some time longer, and to note whether the general behaviour of the pendulum has any intimate connection with the meteorological conditions. We intend to observe whether there is a connection between the degree of agitation of the pendulum and the occurrence of magnetic storms. M. Zöllner has thrown out a suggestion for this sort of observation, but we find no notice of his having acted on it.[1]

We shall also test how far the operation by means of the back-leg may be made to satisfy our expectations.

We have no hope of being able to observe the lunar attraction in the present site of observation, but we think it possible that we may devise a portable instrument, which shall be amply sensitive enough for such a purpose, if the bottom of a deep mine should be found to give a sufficiently invariable support for the instrument.

The reader will understand that it is not easy to do justice to an

[1] *Phil. Mag.* Dec. 1872, p. 497.

incomplete apparatus, or to give a very satisfactory account of experiments still in progress; but as it is now two years since the Committee was appointed, we have thought it best to give to the British Association such an account as we can of our progress.

Second Report of the Committee, consisting of Captain ABNEY, Professor W. G. ADAMS, *and* Professor G. CAREY FOSTER, *appointed to carry out an Investigation for the purpose of fixing a Standard of White Light.*

SINCE the last meeting of the Association but little progress has been made in the investigations. Though several series of experiments have been made, no definite conclusion on the subject has been arrived at by your Committee. Owing to the accidental omission to present a report to the last meeting, the recommendation embodied in the communication which was printed in the last annual volume could not be carried out. (See 'Reports Brit. Assoc.' 1880, p. 119.)

Final Report of a Committee, consisting of Professor A. S. HERSCHEL, Professor W. E. AYRTON, Professor P. M. DUNCAN, Professor G. A. LEBOUR, Mr. J. T. DUNN, *and* Professor J. PERRY, *on Experiments to determine the Thermal Conductivities of certain Rocks, showing especially the Geological Aspects of the Investigation.*

IN bringing to a close the series of Reports which it has submitted during the past series of years since 1874, the Committee has endeavoured to collect and to compare together the several exact and well-deduced results from observations arrived at hitherto by various independent experimenters and investigators in the subject of its inquiry, so as to show at once the present position of the experimental research and the most essential points in which it requires further extensions and improvements.

The method pursued by Professor Everett in his work on 'Units and Physical Constants,' of expressing all the well-determined data of physical experiments in terms of the centimètre, the gramme, and the second as a common system of units, is adopted in forming the general list of absolute and relative thermal conductivities by different observers, which the Committee has met with and collected together in the simple order and arrangement of a classified Table of thermal properties of rocks presented with this Report. Many of the data presented in the Table are therefore already furnished in the uniform and well-authenticated form required, in Professor Everett's work. But the result of the present comparison has afforded the Committee such positive grounds of confidence in the general accuracy of the values found by its long-continued series of experiments, that it has been enabled by that means to assign absolute values to the relative ones of several important lists of thermal conductivities which, on account of their relative values only, could not receive admission to the store of absolute data furnished by Professor Everett's descriptions and reductions. In relation to this procedure the example of Péclet has been followed in the present list, who, in 1841, adopting relative numbers found by Despretz in 1821 and 1827, assigned absolute values to Despretz's series, by means of his own absolute determination of the thermal conductivity of one of the substances (statuary marble) examined by Despretz. The values so assigned conjointly by Péclet and Despretz are marked 'Despretz (α)' in the Table. But in a later relative list of Despretz, of a few specimens of rocks tested in 1852 (not used, apparently, by Péclet in his general list of 1853), the value given for marble, for reduction of Despretz's earlier list, is not adhered to in the present Table, but the average conductivity found by a number of experiments of the Committee on different marbles is used instead of it, and Despretz's relative values thus converted into absolute ones are marked 'Despretz (β), 1852,' in the present list.

A similar course had to be pursued in the case of two important relative researches published almost simultaneously in 1856 and 1857 by Helmersen of St. Petersburg, and Hopkins of Cambridge, on thermal rock-conductivities. To the relative quantities given by those researches for vein-quartz and white statuary marble respectively, the average values of the absolute conductivities of those rocks found by the Committee's repeated observations of them, are assigned (with a slight deviation in the latter case for the reasons recognised below), to convert the other relative quantities of the two researches into absolute measure, and to allow of their being compared on a common scale with other absolute determinations in the general list.

The work of Helmersen terminated in recording the observed temperatures along bars of the tested specimens one and a-half inch square and eighteen inches long, heated at one end, according to Despretz's method. Four thermometers being distributed at equal distances along the bars, it was found that in the worst-conducting bars the logarithmic decrement of temperature was so far from uniform and constant, that abandoning the doubtful measurement of its true value in each of them, Helmersen was contented to conclude from his experiments that vein-quartz was the best conducting material of those which he examined.

As, however, unusual care was bestowed on Helmersen's experiments, the relative quantities which they denote are yet of great value for corroborative estimations. The decrements for each bar, and for each interval between the four thermometers, was therefore deduced from them, and by a mode of reduction to a mean decrement for each bar used independently of each other by two of the Committee to reduce the observations with the best presumptive regard to their respective weights, to relative conductivities, the following two series of numbers were obtained:—

Rock Specimen		Quartz	Mica Schist	Granite	Marble	Porphyry	Serpentine	Sandstone	Limestone
Relative Conductivity, k	I.	·00710	·00501	·00356	·00510	·00448	·00555	·00471	·00466
	II.	·00688	·00563	·00375	·00412	·00371	·00458	·00508	·00399

Of these two series preference has been given to the latter, as it gives more weight to the thermometric intervals near the source of heat, thar to those near the cool end of the bars, where the stationary temperatures shown by the thermometers inserted in the bars were, in general, very little in excess of the temperature of the surrounding air. The numbers in this series were divided by 0·72 to make that for quartz correspond to the thermal conductivity 0·0096, found for that substance as the average result of the Committee's experiments described in former years in these Reports. The constant rate of logarithmic decrement in the quartz-bar, in fact, shows that its conductivity was more exactly measured by that quantity than in the case of the other bars whose rates of logarithmic decrement were very variable.

The processes of experiment used by Hopkins and by Less to compare together the thermal conductivities of two considerable series of rocks, were those of Fourier and of Péclet, with some slight modifications, and they differ principally from the latter, and from that employed in the experiments of these Reports, in not affording the absolute, but only the relative, conductivities of the tested plates. In both mercury was used to establish direct contact between the plates and the heater and cooler between which they were interposed; and the heat traversing the plate from below in the former, escaped to the surrounding air from the bright fluid surface of the upper covering of mercury whose temperature, and that of the mercury below the plate was at the same time observed. In Less's experiments the heat which passed downwards escaped to the outer air from a blackened copper plate pressed (like a heated one above) against the rock plate with a wet-junction of mercury. A thermopile placed opposite to the radiating-plate enabled its temperature to be observed.

The numbers (relative ones) 763 and 769, found by Less for Italian and Carrara marbles are higher than the Committee's absolute (significant) numbers (57 and 61) of white marbles from Italy and Sicily; the same being in general the case throughout the two lists. The numbers of Less's list have all been diminished by one-tenth to assimilate them to and incorporate them in the present general list. But no alteration of the significant relative numbers obtained by Hopkins from his experiments was found to be required, the slightly defective number, 53, for statuary marble being compensated, especially in some granites and hard rocks, by a little excess of the relative numbers above those obtained by the Committee as absolute ones for quartz and granite. Accordingly, in the general list the relative numbers given by Hopkins have been used directly in a proper decimal place to give average absolute values of the conductivities which he found for certain different groups of common descriptions of rock tested in his experiments.

Other observations, especially those of Péclet and Neumann, are originally absolute determinations.

Of the original memoirs from which these data were extracted, and also of a long series of other papers relating to measurements of thermal conductivity, which mainly comprise the past history of its experimental investigation, a descriptive index and digest was drawn up for the Committee by Mr. Dunn. Of this abstract, as it supplies references, and further particulars of the experiments which have just been described, and as it affords a condensed review of the progress of experiment on the physical properties which here claim attention, the titles and substances of the publications which have most eminently extended and advanced the subject are added at the end of this Report, as an Appendix.

The appearance, in the first quarter of this century (in the year 1822), of Fourier's work on the laws of heat-conduction, and later on (in the year 1835) the production by Poisson of a similar treatise, together with publications by these and by Rudberg, Quetelet, Kuppffer, and other writers of distinction on the same subject in the interval between those dates, directed the attention of those concerned in investigations of terrestrial physics to a new method of enquiry regarding the debated question of the globe's internal temperature. Between the upholders of the rival theories of the earth's original igneous, or aqueous consolidation, the reality of the argument of the gradual increase of temperature with depth below the surface of the earth was clearly demonstrated and established at about that time by the works of Cordier in France, and of Fox and Henwood in England, on the temperature of mines in deep workings at many different localities of the globe. The evidence which this, now universally established phenomenon presents in the views of Fourier's theory of a waste (presumably constant) of the globe's internal heat, has pointed not only to an extremely high present, but also to a much higher past internal temperature; and the verification and extension of Fourier's theory by legitimate and practicable experimental trials is a course of the greatest speculative, and, without doubt, also of the greatest practical, consequence and interest to geologists. It is a meritorious recollection of its earliest proceedings that, among its first few years' recommendations, the British Association assisted and substantially endorsed these views by directing at that time the establishment in Edinburgh, under a Meteorological Committee, of which Professor Forbes, Professor Phillips, Colonel Sykes, Dr. Apjohn, and other distinguished men of science were most efficient members, of the three series of rock- and earth-thermometers in the trap-rock of the Calton Hill, the sand of the Botanical Garden, and the sandstone of Craigleith Quarry, near Edinburgh, which were read and recorded weekly, and finally reduced to thermal data for the five years following their establishment, from May 1837 to May 1842, by Professor Forbes.[1] The two last of these thermometer-sets were then abandoned, but the weekly readings of that in the Royal Observatory grounds on the Calton Hill in Edinburgh were continued uninterruptedly, until the recent destruction of the instruments, for forty years.

The records of five years during which observations were recorded at all the three sets of thermometers by Professor Forbes, and of thirteen following years, were similarly reduced to thermal data, in the year 1860, by Sir W. Thomson;[2] and Professor Everett also calculated from a seventeen years' period of the same observations a coefficient of con-

[1] *Transactions of the Royal Society of Edinburgh*, vol. xvi. p. 219.—The coefficients of conductivity there arrived at are given, like Poisson's, in French mètres and the year; for trap, sand, and sandstone, $k = 11{\cdot}120$, $8{\cdot}260$, $29{\cdot}884$; requiring for reconversion to Paris-feet (the unit of depth of the thermometers) to be multiplied by 9·477, the square of the number of Paris-feet in a mètre, giving 105·38, 78·28, 283·21. Comparing these figures with those in Paris-feet, 124·2, 78·31, 319·3 given by Sir W. Thomson's discussion on the page quoted below, it will be seen that Sir W. Thomson's citations of Forbes's values ('111·2, 82·6, 298·3') at that place, are erroneous in having only been multiplied by 10, instead of by 9·477, for their conversion; and that the two results for sand are, in fact, almost identical, while sensible differences do actually exist in the values found by Professor Forbes and Sir William Thomson for trap-rock and Craigleith sandstone. The values of Forbes' data entered in the present Table are those furnished directly by the original conclusions as above, of his above-quoted Memoir.

[2] *Ibid.* vol. xxii. p. 405 *et seq.*, (the concluded data on p. 425).

A General List of Observed Specific Heats by Volume, and of Absolute Thermal Conductivities of certain Rocks.

	Specific Heat by Volume c	No. of specimens tested	Extreme range of values from the mean; p. ct.	Absolute Thermal Conductivity k	No. of (experiments and of) specimens tested	Extreme range of specimens' values from the mean; p. ct.	Absolute Thermal Resistance r	Value of the ratio $\frac{k}{c}$	References, Localities, and Descriptions of the Specimens Tested.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Quartzose Rocks.									
Vein-quartz . . .	—	—	—	0·00957	1	—	104	—	Helmersen; (assumed absolute value from the next determination).
Ditto, and Quartzites .	0·47	·5	4·0	·00954	5 (10)	4·5	105	0·0206	These Reports, 1878; various quartzes and quartz rocks.
Hard igneous rocks .	—	—	—	·00995	2	0·5	100	—	Hopkins; two hard rocks from Loch Katrine and Charnwood Forest.
Quartzose Mica-Schist .	—	—	—	·00782	1	—	128	—	Helmersen.
Ganister . . .	0·49	1	—	·0063	—	—	159	·0127	These Reports, 1878.
Granites.									
Granite	—	—	—	·00521	1	—	192	—	Helmersen; fine-grained granite.
Ditto	—	—	—	·00680	6	25·0	147	—	Hopkins; various, with syenite $k = 0·0085$.
Ditto	0·51	1	—	·00550	1	—	182	·0109	Neumann; large-grained granite.
Ditto	—	—	—	·00568	2	6·0	176	—	Less; one ordinary and one albitic granite.
Ditto	0·51	5	5·0	·00601	4 (16)	8·5	166	·0118	These Reports, 1878; various, fine and coarse.
Whin and Trap-rocks									
Basalt	—	—	—	·00560	2	5·0	179	—	Hopkins; from Loch Katrine.
Porphyritic Trap . .	—	—	—	·00590	1	—	169	—	Ayrton and Perry; Porph. Trachyte, from Japan.
Ditto	0·49	1	—	·0054	1	—	185	·0110	These Reports, 1878; from Loch Rannoch.
Whin and Traps . .	0·55	8	7·0	·00360	6 (7)	16·5	278	·0067	These Reports, 1878; from Newcastle, Calton Hill, and Devonshire; with Cornish Elvan.
Calton Hill Trap . .	0·528	1	—	·00352	1	—	284	·00667	Forbes; from rock-thermometers, Edinburgh, five years 1837–42. The specific heat by Regnault.
Ditto	0·528	—	—	·00415	1	—	241	·00786	Thomson; the same, 1837–54, eighteen years.
Ditto	—	—	—	—	—	—	—	·0062	Everett; reductions of the same, for seventeen years.

Basalts	—	—	—	·00531	2	2·5	188	—	Less; from Oberstein and Mitterteich.
Porphyry	—	—	—	·00513	1	—	195	—	Helmersen; albitic, with aphanite.
Mica-Schists and Flagstones.									
Hard Sedimentary Rock	—	—	—	·00550	1	—	182	—	Hopkins; hard blue rock, from Penmaenmawr.
Gneiss	—	—	—	·00514	2	1·5	195	—	Less; two specimens from Tharandt.
Indurated Mica-Schist	0·54	3	2·0	·0052	1	—	192	·0098	These Reports, 1878; from Loch Rannoch.
Micaceous Flagstone	0·51	4	2·0	·00690	3	10·0	145	·0136	Ibid.; from Loch Rannoch, conduction along the cleavage.
Ditto	0·51	5	3·5	·00492	5	10·0	203	·0097	Ibid.; ditto; conduction across the cleavage.
Slates and Shales.									
Slate	—	—	—	·00610	1	—	164	—	Hopkins; from Charnwood Forest.
Ditto	—	—	—	·00403	1	—	248	—	Less; from Carlsbad.
Welsh Slate	0·59	1	—	·00670	1 (2)	—	149	·0115	These Reports, 1878; conduction along the cleavage.
Ditto	0·58	2	3·0	·00395	3 (4)	8·5	253	·0068	Ibid.; conduction across the cleavage.
Clay-slate	—	—	—	·00352	1	—	284	—	Less; from Schwartzthal.
Ditto	0·52	3	3·0	·00303	2 (3)	1·5	330	·0060	These Reports, 1878; from Christow, near Exeter.
Grey and Black Shale	0·61	2	2·5	·00235	2 (3)	28·0	425	·00375	Ibid.; from Newcastle.
Altered Shale	0·52	2	5·0	·00405	2 (2)	14·5	247	·0077	Ibid.; from Alnwick, Northumberland.
Sandstones.									
Hard Sandstones	—	—	—	·00663	6	14·5	151	—	Hopkins; chiefly from Dukenfield and Chapel-le-Frith.
Ditto	[0·47]	—	—	[·00637]	—	—	[157]	·01355	Neumann; 'grès'; [with assumed specific heat of hard sandstones, these Reports, below.]
Craigleith Sandstone	0·462	1	—	·00947	1	—	105	·0205	Forbes; Edinburgh rock-thermometers, 1837–42. Specific heat by Regnault.
Ditto	0·462	—	—	·01068	1	—	93	·02311	Thomson; ditto, 1860; with Regnault's specific heat.
Ditto	0·405	6	8·5	·00866	6 (7)	13·5	115	·02131	These Reports, 1878; various specimens from the quarry.
Hard Sandstones	0·47	7	17·0	·00672	7 (9)	22·0	149	·0143	Ibid.; several localities. Prudham, and Galashiels red $k = 0{\cdot}008$, $c = 0{\cdot}39$ and 0·46.
Sandstone	—	—	—	·00706	1	—	142	—	Helmersen; fine-grained, argillaceous.
Soft Sandstones	—	—	—	·00397	5	50·0	252	—	Hopkins; various kinds; New red, $k = 0{\cdot}0025$ (dry), $= 0{\cdot}0060$ (wet).

A TABLE OF OLSERVED SPECIFIC HEATS, &c.—*continued.*

	Specific Heat by Volume c	No. of specimens tested	Extreme range of values from the mean; p. ct.	Absolute Thermal Conductivity k	No. of (experiments and of) specimens tested	Extreme range of specimens' values from the mean; p. ct.	Absolute Thermal Resistance r	Value of the ratio $\frac{k}{c}$	References, Localities, and Descriptions of the Specimens Tested
Sandstones.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Soft (?) Sandstones .	—	—	—	·00436	4	28·0	229	—	Less; from Germany; two with chalk, and kaolin cement.
Firestone (green sand) .	0.34	2	3·0	·00240	2	—	427	·0066	These Reports, 1878; from Godstone Chalk-hills.
Marbles.									
White Marble . . .	—	—	—	·00480	1	—	208	—	Péclet, 1841; gives absolute values to Despretz' relative series, 1821–27 (α).
Statuary Marble . .	—	—	—	·00530	1	—	189	—	Hopkins; (using his relative as absolute numbers in this list).
Marble	—	—	—	·00572	1	—	175	—	Helmersen; fine-grained.
Ditto	—	—	—	·00633	3	18·5	158	—	Less; Pyrenean (·0080) and Italian Marbles (·0059).
Ditto	0·59	9	13·0	·00585	5 (13)	5·0	171	·0103	These Reports, 1878; white, coloured, and fossil marbles.
Ditto	—	—	—	·00585	—	—	171	—	Despretz, 1852 (series β); assumed absolute value from the last determination.
Ditto	—	—	—	·00870	2	11·5	114	—	Péclet, 1853.
Compact Limestones.									
Mountain Limestone .	—	—	—	·00550	1	—	182	—	Hopkins; from Derby.
Limestone . . .	—	—	—	·00554	1	—	181	—	Helmersen.
Lithographic ditto . .	—	—	—	·00805	1	—	124	—	Despretz (β), 1852.
Limestone . . .	—	—	—	·00467	3	17·0	214	—	Péclet, 1853.
Ditto, and Calcite . .	0·545	7	10·0	·00620	3	9·5	161	·0109	These Reports, 1878; mountain limestone and vein-stuff.
Porous Limestones.									
Oolite	—	—	—	·00370	3	—	270	—	Hopkins; three specimens from Ancaster.

Oolitic Limestone . .	—	—	—	·00270	1	—	370	—	Despretz (β), 1852; from Tonnère; well-dried.
Lias Building Stone .	—	—	—	·00360	2	3·0	278	—	Péclet, 1853; coarse-grained.
Lias and Magnesian Limestones.	0·435	5	22 0	·00522	5 (6)	15·0	192	·0121	These Reports, 1878.
Chalk.									
Chalk, well-dried . .	—	—	—	·00170	1	—	588	—	Hopkins.
Chalk	0·36	1	—	·00220	1	—	455	·0063	These Reports, 1878; from Godstone.
Coal.									
Coal	—	—	—	—	—	—	—	·00116	Neumann.
House-coal . . .	0·47	1	—	·00068	1	—	1470	·0014	These Reports, 1878; from Newcastle.
Cannel Coal . . .	0·40	3	6·0	·00120	1 (2)	—	787	·0030	Ibid.; from Blaydon, Newcastle.
Clay.									
Dry Clay . . .	—	—	—	·00250	2	8·0	400	—	Hopkins; two specimens, dry, and very dry.
Wet ditto . . .	—	—	—	·00370	1	—	270	—	Ditto.
Very wet Clunch . .	—	—	—	·00300	1	—	333	—	Ditto.
Dry Clay . . .	—	—	—	·00206	1	—	485	—	Less.
Wet ditto . . .	0·810	1	—	·00377	1	—	265	·00466	Ångström, 1860 (*circa ?*); reduction of Upsala earth-thermometer records.
Dry Clay . . .	0·46	1	—	·00250	1	—	398	·0054	These Reports, 1878; tough, sun-dried.
Wet ditto . . .	0·85	1	—	·00350	1	—	286	·0039	Ibid.; the same clay, pugged soft.
Brick, and Baked Clay									
Brick and Porcelain .	—	—	—	·00240	2	4·0	417	—	Despretz (α), 1827; (Péclet, 1841).
Terracotta . . .	—	—	—	·00167	2	15·0	599	—	Péclet, 1853.
Brick, dry . . .	0·335	4	1·5	·00180	2	5·5	556	·00545	These Reports, 1878; fire and building brick.
Ditto, wet . . .	0·62	4	6·0	·00335	2	16·5	300	·00545	Ibid.; the same plates, thoroughly wet.
Sand, Gravel, &c.									
Quartz-sand . . .	—	—	—	·00075	1	—	1333	—	Péclet, 1853.
Siliceous Powder . .	—	—	—	·00150	1	—	667	—	Hopkins.
Argillaceous ditto . .	—	—	—	·00070	1	—	1429	—	Ditto.
½ Sil. and ½ Argil. ditto	—	—	—	·00110	1	—	909	—	Ditto.
Calcareous ditto . .	—	—	—	·00056	1	—	1786	—	Ditto.
Powdered Chalk . .	—	—	—	·00028	3	13·5	3572	—	Péclet, 1853; coarse and fine-pounded.
Pounded Brick . .	—	—	—	·00041	3	7·5	2440	—	Ditto.
White Siliceous Sand, dry.	0·29	1	—	·00105	1	—	952	·0036	These Reports, 1878.

A TABLE OF OBSERVED SPECIFIC HEATS, &c.—*continued.*

	Specific Heat by Volume c	No. of specimens tested	Extreme range of values from the mean; p. ct.	Absolute Thermal Conductivity k	No. of (experiments and of) specimens tested	Extreme range of specimens' values from the mean; p. ct.	Absolute Thermal Resistance r	Value of the ratio $\frac{k}{c}$	References, Localities, and Descriptions of the Specimens Tested
Sand, Gravel, &c.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
White Siliceous Sand, thoroughly wet.	0·57	1	—	·00820	1	—	122	·0144	These Reports, 1878; the same sand saturated.
Garden Sand . . .	0·3006 (dry ?)	1	—	·00262	1	—	382	·00871	Forbes; earth-thermometers in garden-sand, Edinburgh, 1837–42; specific heat by Regnault.
Ditto	0·3006	—	—	·00262	1	—	382	·00871	Thomson, 1860; reduction of the same observations, with Regnault's specific heat.
Gravel	—	—	—	—	—	—	—	·01249	Everett; reduction of Royal Observatory, Greenwich, Earth-thermometer observations, 1847-59.
Frozen Mould . .	—	—	—	—	—	—	—	·00916	Neumann.
Coarse Sand . . .	—	—	—	—	—	—	—	·00605	By yearly ranges of 1 ft., 2 ft., 3ft., earth-thermometers, Rudberg at Stockholm, two half-years, 1832–33.
Ditto	—	—	—	—	—	—	—	·00715	Reduction of the same thermometers for two half-years, 1833–34; by Quetelet.
Ditto	—	—	—	—	—	—	—	·00935	Ditto, ditto, for one whole year, 1834, by Ångström, 1851.
Sandy Clay . . .	—	—	—	—	—	—	—	·00566	Ångström, 1851; reduction of earth-thermometers (2, 4, 6, and 10 ft.), at Upsala, seven years, 1838–44.
Argillaceous Sand . .	0·762	—	—	·00342	—	—	292	·00449	Ångström; by Upsala earth-thermometer reductions; 1860 *circa ?*
Miscellaneous Rocks.									
Ice	—	—	—	·00213	—	—	469	—	De la Rive.
Ditto	—	—	—	·00218	—	—	459	—	G. Forbes.
Ditto	[0·46]	—	—	[·0052]	—	—	192	·0114	Neumann.
Snow	—	—	—	—	—	—	—	·00356	Ditto.

Serpentine	—	—	—	·00636	1	—	157	—	Helmersen; hard serpentine.
Ditto	0·70	—	—	·00416	—	—	240	·00594	Neumann; from Toplitz.
Ditto	—	—	—	·00507	1	—	197	—	Less; Saxon-Harz serpentine.
Ditto	0·68	2	3·0	·0050	1 (2)	—	202	·0073	These Reports, 1878; red and green, from Cornwall.
Plaster of Paris	—	—	—	·00092	1	—	1087	—	Péclet, 1853; ordinary plate.
Ditto	—	—	—	·00133	2	8·0	752	—	Ditto; finest plaster plates.
Ditto	0·27	1	—	·00135	1	—	740	·0051	These Reports, 1878; fine plaster, a light plate.
Gypseous Alabaster	0·65	1	—	·0036	1 (2)	—	278	·0056	Ibid.; English hydrated calcic sulphate.
Heavy Spar	[0·48]	—	—	·0020	—	—	500	[·0042]	Ibid.; crystalline plate, Christow, Devonshire.
Fluor Spar	0·62	1	—	·0108	1 (2)	—	93	·0180	Ibid.; ditto, from Derwent-dale, Newcastle.
Rock Salt	0·40	1	—	·0128	1 (2)	—	78	·0324	Ibid.
Pumice-stone	0·14	1	—	·0006	1	—	1616	·0043	Ibid.; sp. gr. 0·6, dry.
Ditto, wet	0·61	1	—	·0012	1	—	863	·0019	Ibid., 1879; the same plate, thoroughly wet.
Magnesite	0·45	1	—	·0044	1	—	227	·0098	Ibid., 1879.
'Laterite' (?)	—	—	—	—	—	—	—	·00743	Reduction of Caldecott's Trevandrum earth-thermometers. three years, 1843–45, by Ångström, 1851. Depths, 3, 6, 12 ft.
Earth-thermometer Localities.									
Zürich, 1760; seven depths, ¼ ft. to 6 ft.	—	—	—	—	—	—	—	·00865	By Kuppffer's mean logarithmic rate from Ott's records for four years (assumed in Paris-ft.); Poggendorff's Annals, vol. 32, 1834.
Raith, Edinburgh, 1816–17; four depths, 1, 2, 4, 8 ft. (? English).	—	—	—	—	—	—	—	·00444	By Kuppffer's mean rate from Leslie's records for two years (assumed in English-feet. ?). Ibid., 1834.
Ibid.; the same.	—	—	—	—	—	—	—	·00868	By reduction of the same records for the two lowest depths (4 and 8 ft.) only.
Strasburg 1821–23; one depth, 15 ft.	—	—	—	—	—	—	—	·01267 ?	By Kuppffer's mean rate from Hemmschneider's records for three years; [the thermometer (?) externally affected]. Ibid., 1834.
Brussels, 1834–35; seven depths, ½ to 24 Paris-ft.	—	—	—	—	—	—	—	·01200	From the mean logarithmic rate of a reduction, by himself, of Quetelet's records at Brussels for two years. Ibid., vol. 35, 1835.
Paris, 1834–5 (?)	—	—	—	—	—	—	—	·00830	From Poisson and Bouvard's reduction of Arago's unpublished records; in Poisson's 'Théorie Mathématique de la Chaleur,' 1835.

ductivity for the Trap of Calton Hill scarcely distinguishable in its value from that found by Sir W. Thomson.[1]

Transforming these determinations to centimètres, grammes, and seconds from the units of the Paris-foot and year in which they are expressed, the corresponding values of the absolute thermal coefficients so obtained for Calton Hill trap-rock are arranged with those obtained from the Committee's experiments, in the accompanying general list. Similar values in the same list denote also, in comparison with the Committee's observations, the absolute conductivities (by unit-weight of water and by unit-volume of the rocks) found by the two independent methods for the sandstone of Craigleith quarry and for the sand of the experimental garden, near Edinburgh, where the other thermometers were planted.

The directly measured values are in general, in these cases, in such very fair agreement with the thermal conductivities found by computations, that the verifications which they afford of those results are also a substantial confirmation of the theory upon which they are founded. Ångström's reductions of the 10 feet deep Upsala earth-thermometers in moist clay afford the same conclusion; and indeed the agreement presented by the series of Despretz's, Helmersen's, and Neumann's observations, and especially by Messrs. Ayrton and Perry's experiment on a sphere of trachyte, made by methods based on Fourier's theory, with the direct results of various forms of Péclet's method used in the other determinations of the table, plentifully attest and abundantly substantiate the same physical agreement.

There are, indeed, as great difficulties in determining thermal conductivities from earth-thermometer observations, as in successful applications of the processes of direct experiment. For while in the latter artificial temperature and heat-supplies are difficult to keep constant and to measure accurately, in the former case the natural periodical variations which furnish observational results for computation, are uncertain in their separate and combined intensities and effects from year to year. It is only on the average of several years' records that the annual, semi-annual, and other quicker oscillations of temperature at the earth's surface can be regarded as sufficiently constant for a single average period to be severally followed downwards by calculation, as individual heat-waves among the deep-sunk thermometers. In this case the same rate of decrease per foot of logarithmic amplitude, and of angular lead of the maximum or minimum phase of the descending heat-wave, would be found for all the annual, semi-annual, and other quicker portions of the oscillation at the surface. The same value of the earth's conductivity, at any place, would be found from all these periods. But the varying character, at any place, of the yearly oscillations of temperature at the earth's surface from year to year, precludes the possibility in general of such perfectly accordant calculations, for records not extending over more than one or two years. Reductions, like Sir W. Thomson's and Professor Everett's, for records extending over periods of seventeen or eighteen years, show very close approximations to it. But in briefer periods the effect on range and retardation near the surface, produced by half-yearly and other faster oscillations, is not always found to be compatible with that attributable to the yearly one, from secular changes of greater period than either being accidentally combined

[1] *Transactions of the Royal Society of Edinburgh*, vol. xxii. p. 437.

with them, of which only long-continued observations can by a final average eliminate the inconstant actions.

With all the loss of certainty which thence arises, the records of earth-thermometers for one or two years only have frequently been reduced, so as to afford approximate coefficients of amplitude-decrease and retardation, from which corresponding conductivities in terms of the heat capacity of a unit-volume of the rock-substance, and of the centimètre, gramme, and second, as fundamental units, are easily calculated, when the fundamental units are known in which the concluded coefficients were expressed. Coefficients of this kind were deduced by Kuppffer from Ott's extensive three-year observations at Zürich about the years 1760–62, and from Dr. Leslie's, at Raith, near Edinburgh, in 1816 and 1817. The equivalents of these coefficients given in the table in the column of the ratio $\frac{k}{c}$, assume the units in which they were originally expressed to have been, the Paris-foot in the former, and the English-foot in the latter reduction, those having been apparently (in the absence of other intimations in Kuppffer's work), the scale-units of depth of the Zürich and Raith thermometers used and adopted by Kuppffer in his calculations. The conductivity derived directly from the recorded loss of range, which was nearly the same in one year as in the other, between the two deepest (4 feet and 8 feet deep) thermometers at Raith in 1816 and 1817, differs so much from that belonging to the higher seated ones (at 1 foot, 2 feet, and 4 feet deep), and from Kuppffer's mean value of the rate of logarithmic decrement for the whole of the records at the different depths, that in view of the probability of the lowest pair of thermometers being least of all affected in their ranges by temperature-oscillations of short periods at the surface, a separate entry is given in the Table of the value of the ratio $\frac{k}{c}$ derived from the two lowest thermometers only, on the supposition here adopted of its being more certainly dependable than that arrived at from all the thermometer indications together, without any choice or preference.

Another logarithmic rate instanced by Kuppffer in the same paper as the last two, is deduced from three' years observations at Strasburg, by Hemmschneider, in 1821–23, of a thermometer fifteen feet below the surface of the earth. This reduction seems to be as doubtful and uncertain as that last described, and the equivalent conductivity $\frac{k}{c}$ is as high (0·01267) as that denoting Kuppffer's mean rate for the Raith thermometers is low (0·00444) among ordinary values. But from Rudberg's one- to three-feet deep thermometer records in the Observatory plain of coarse sand at Stockholm, three reductions for one year each, 1832–33, 1833–34, and 1834 alone (the last two by Quetelet and Ångström) give conductivity equivalences 0·0060, 0·0071, and 0·0093 very divergent but generally resembling those found by Forbes and Thomson, ·0067, ·0079, and ·0087 for Calton Hill trap-rock and garden-sand. The Committee's experiments gave ·0036 for dry, and ·0144 for thoroughly water-saturated fine siliceous sand. But the source of divergence in the apparent geothermal conductivity at Stockholm was more probably, as Ångström recognised, in comparing Quetelet's with his own result, the irregular course of temperature at the locality in two successive years, than possible variations at the place of the soil's dryness or wetness during the same time. The high value of the stratum-conductivity, found by Quetelet, in two years at Brussels, for earth of the deep-sunk thermometer bed, established and observed there in 1834 and 1835 (0·0120), may, perhaps, for the same reason, be in some measure accidental; but no errors of the same kind can be easily supposed to affect the widely different value (0·0057) which Ångström's reduction in 1851, of seven years' records of the deep-sunk thermometers, at Upsala, gave for the uniform bed of sandy clay in which those thermometers are placed.

The surface-stratum conductivity given by Poisson's reduction, in his 'Théorie Mathématique de la Chaleur,' of Arago's unpublished earth-thermometer observations in Paris (0·0083), and that assigned by Ångström's discussion of Caldecott's observations for three years of deep-sunk thermometers in 'laterite,' at Trevandrum (0·0074), are both of average or ordinary magnitudes. Two values, however, obtained subsequently by Ångström, apparently from earth-thermometer records at Upsala, for wet clay and argillaceous sand (0·0047 and 0·0045), are again remarkably low quantities compared with the well-established conductivities in terms of heat-capacity by volume (0·0205 or 0·0231) found by Forbes and Thomson to belong to Craigleith sandstone.

Of the existence, therefore, in different rocks and soils, of great diversity in their powers of transmitting heat-waves, or periodical and other fluctuations of temperature, the hitherto conducted observations of earth-thermometers have given abundant proofs and illustrations. It redounds, indeed, especially to the well-earned scientific prestige of the British Association that this result has been arrived at by one of its earliest initiatives and promotions of scientific objects in no small degree; for by its timely establishment and careful choice of the sites of the Edinburgh rock- and earth-thermometers, a thermal property of the pure Craigleith coal-measure sandstone has been revealed, to which no other earth-thermometer records and reductions yet made have hitherto presented any parallel. The geothermal conductivity of this kind of sandstone is nearly twice as great as that of any other earth-stratum hitherto tested with thermometers, and five or six times as great as that of moist clay and argillaceous earth tested by the same mode of observation.

An error of reduction which affected all the Committee's absolute conductivity-determinations, was noticed after the production in the volume of these Reports for the year 1878, of the last general table of the Committee's observations. The necessary correction which it entailed upon the list was notified in the following report (in the volume of these Reports for the year 1879), and corrected values of several of the results before obtained were then communicated. The required corrections have now been applied to the whole of the measurements contained in the last general table, and the numerous trials made in several cases of rocks of the same class and geological description have been incorporated, owing to the close similarity which in general subsists between them, into single average results for the several distinct classes or geological kinds of rock. The comparison which can thus be formed in the accompanying general list between these measurements and those obtained by other methods and researches is in general very satisfactory, and exhibits in many cases corroborations of very excellent accordance.

The confirmations desired by Poisson of the applications of Fourier's theory to the problem of heat and temperature-distribution and changes in the interior of the globe, by instrumentally measured values of the thermal coefficients to which they either lead, or which, on the other hand, they require for their extensions, are now at least partially supplied. But it must be admitted that many imperfections of experimental methods, as well as intricacies of the theory's applications, still remain to be removed before the confirmation and assistance which one branch of the subject of heat-conduction can derive from and may usefully offer to the other, can yet be satisfactorily affirmed to be complete.

Upon this point, which embraces the geological aspect and objects of the present investigation in its widest sense, much more might be written and comprised in this report which the Committee has noted and collected in its work of original reference and research. But as these notes and historical reviews would lead to the extension of this report much beyond its contemplated length, the Committee deems it necessary, in its concluding report, to confine itself to the results of recent work and publications which bear most immediately upon the experimental part of the problem regarding whose progress and recent investigations it has, during the long period now terminated of its frequent reappointment, chiefly endeavoured to record the useful acquisitions, and to present together an outline of the best existing information.

APPENDIX.

Abstracts of Papers relating to the Conduction of Heat, and a List of Authors' Names and Writings on the Subject. By J. T. DUNN.

Dalton, 'Ann. Chim.' (1), 45, 177 (1803).—Method of determining point of maximum density of H_2O by thermometers.

Despretz, 'Ann. Chim. Phys.' (2), 19, 97 (1821).—The first of the well-known memoirs. Results: Cu 12; Fe, Zn, Sn, 5; Pb, 2; marble, $\frac{5}{16}$; brick clay, porcelain, $\frac{5}{32}$.

Despretz, ib. (2) 36, 422 (1827).—Extension of former results, with numerical details of experiments. Good conductors satisfy Fourier's exponential law, but the successive quotients with bad conductors differ widely. Figures:—

Au	1000	Cu	898·2	Sn	303·9	Porcelain	12·2
Pt	981	Fe	374·3	Pb	179·6	Brick and firebrick	11·4
Ag	973	Zn	363·0	Marble	23·6		

Fourier, ib. (2) 37, 291 (1828).—Conducting powers of thin films. A thermometer is immersed in Hg in a conical iron vessel with a flexible skin-bottom. This having been warmed to a suitable temperature is placed on the film or lamina lying on a block of constant temperature, and the fall of the thermometer noted Comparative results only. An air-thermometer has the lower half of its bulb in contact with the lamina, which again is in contact with a hot body of constant temperature, while the upper half of the thermometer-bulb is in contact with melting ice. Order of conductivity given by the temperature which the thermometer takes up.

De la Rive and Decandolle, ib. (2) 40, 91 (1829).—Conductivity of woods. Same method as Despretz. End of bar cased in tinplate and heated by spirit lamp. Order of conductivity only. Allier (*Cratægus aria*), walnut, oak, pine, poplar (long.). Walnut, oak, pine (trans.). Cork (long.).

Lamé, ib. (2) 53, 190 (1833).—Theoretical remarks on isothermal surfaces.

Despretz, ib. (2) 71, 206 (1839).—Liquids. Heated from surface in deep cylinder. Temperatures of thermometers follow same law as in solid bar. At same level temperature diminishes from axis towards side, and thence to middle of wall. With cylinders of different diameters temperature-differences agree with theory.

Péclet, ib. (3) 2, 107 (1841).—The well-known method. Result for Pb k = 3·84 (1 kilo. H_2O 1° C. 1 sq. m. 1 mm. 1 sec.). Hence, from the results of Despretz, Au = 21·28, Pt = 20·95, Ag = 20·71, Cu = 19·11, Fe = 7·95, Zn = 7·74, Marble = ·48, Porcelain = ·24, Fireclay = ·23.

Senarmont de, ib. (3) 21, 457, and 22, 179 (1848).—Crystals. Covered with wax, and heated either by spot of sunlight, by voltaic ignition of Pt wire bored through, by stream of hot air through silver tube, or by conduction in silver rod. Conductivity varies much as optic elasticity does. In cubic system, surface is a sphere; in square prismatic or rhombic, ellipsoid of revolution, with unequal axis coinciding with axis of symmetry; in rectangular prismatic, ellipsoid axes coinciding with axes of crystal; in monoclinic, ellipsoid with one axis in axis of symmetry, others not predicable; in anorthic, no axis predicable.

Senarmont de, ib. 23, 257. Stress and conductivity. Glass, porcelain, and flint compressed, and the old method used. Axis in direction of compression always shortened, and *vice versâ*.

Wiedemann and Franz, ib. 41, 107 (1854). Metals. The method of Langberg, using thermopile with mechanical means of ensuring contact, and calibrating the indications by direct comparison with thermometer. Results in air differ slightly from those *in vacuo*.

						Pt	8·4
Ag	100·0	Brass	23·1	Fe	11·9	Pd	6·3
Cu	73·6	„	24·1	Steel	11·6	Rose	2·8
Au	53·2	Sn	14·5	Pb	8·5	Bi	1·8

Wiedemann, ib. 45, 377 (1855).—Same method applied to junction of two metals. Appeared at first that there was a sudden fall at the junction when better conductor was hotter, but none when bad conductor was hotter. This, however, found to be due to rate of communication of heat to thermo-pair, and when thermo-pair was immersed in Hg in each bar no difference of temperature was found at the junction.

Gouillaud, ib. (3) 48, 47 (1856).—Metals (Fe, Zn, Pb). Despretz' method, only using longer bars. Verifies experimentally the formulæ $y = T\epsilon^{-ax}$, and $y = A\epsilon^{ax} + B\epsilon^{-ax}$ between the limits for which Newton's law holds. Verifies also the law of thicknesses as Despretz did for liquids. Deduces and verifies that the constant A in expression—$y = A(\epsilon^{ax} - \epsilon^{-ax}) + T\epsilon^{-ax}$—varies directly as the excess of temperature of the source, and shows that without sensible error the formula may be put in the form (2E being the thickness of the bar and l its length), $y = \frac{2 - aE}{2 + aE} T\epsilon^{-2al}(\epsilon^{ax} - \epsilon^{-ax}) + T\epsilon^{-ax}$.

Wiedemann, ib. (3) 58, 126 (1860).—Alloys. Calvert and Johnson's paper appears to show that with alloys the thermal and electric conductivities do not agree as with metals. According to these results they do. Thermal conductivity determined by W. and F.'s method, electrical by Wheatstone's Bridge comparison with zinc wire.

	Th.	El.
Cu	73·6	79·3
8 Cu 1 Zn	27·3	25·5
6·5 „	29·9	30·9
4·7 „	31·1	29·2
2·1 „	25·8	25·4
Zn	28·1	27·3
Sn	15·2	17·0
3 Sn 1 Bi	10·1	9·0
1 Sn 3 Bi	5·6	4·4
„ 1 Pb	2·3	2·0
Rose's metal (1 Sn, 1 Pb, 2 Bi)	4·0	3·2

With Cu Zn alloys, conductivity is nearly same as that of Zn. With Sn Bi alloys, conductivity is about the mean of those of constituents.

Neumann, ib. (3) 66, 183 (1862).—Variable state observed. For metals, bars provided with thermo-pairs near either end heated to stationary state, then sum and difference of thermo-currents observed periodically while cooling. (Sum dependent on h, difference on k.) For bad conductors, cubes or spheres with central and external thermo-pairs similarly treated. (To convert units to Péclet's, multiply by ·0848; to Ångström's, by ·0509.)

	$\frac{K}{cD}$		K
Oil	1·37	Cu	1306
Sulphur	1·68	Brass	356
Ice	13·5	Zn	362
Snow	4·2	German silver	129
Frozen soil	10·8	Fe	193
Sandstone	16·0		
Large-grained granite	12·9		
Serpentine (Zöplitz)	7·0		

Ångström, ib. 67, 379 (1863).—Bar, exposed at one section to periodic heating and cooling, and K deduced from observations of periodic temperatures at other portions. Cu 54·62, Fe 9·77 (grm. cm. min.).

Jannettaz, ib. (4) 29, 5 (1873).—Crystals. Method essentially de Senarmont's, but modified and improved in details (plates of apparatus given). Confirms, on a large number of crystals, the general results obtained by de Senarmont as to relation of axes of conductivity to crystallographic axes and cleavage.

T. Thompson, 'Nich. Journ.' 1, 81 (1802). Regarding convection. Experiments to prove that the motions of amber in Rumford's experiment do not imply currents in the fluid. Two layers of fluid, coloured and colourless, superposed and containing solid particles. On heating, the solid particles travel beyond the coloured into the colourless fluid, without being accompanied by coloured fluid.

Murray, ib. 1, 165, and 241. Conduction in fluids. Rumford's experiments with heating from below inconclusive, prove only that not all the transference of heat in a fluid is conduction. Heating from above, by hot oil poured on water, or brass ball immersed in it over thermometer-bulb, thermometer rose. But this, perhaps, partly from conduction by sides. That sides do conduct shown by jacketing cylinder with outer one filled with water and containing thermometer, outer thermometer likewise rose. To obviate errors from this, made vessel of ice with thermometer frozen through side, filled with oil or Hg, and warmed by hot water poured into can floating or suspended on surface of liquid. Thermometer rose in all cases. Not radiation, because when hot water suspended just over surface of fluid without touching, rise of thermometer exceedingly slight.

Traill, ib. 12, 132 (1805).—Fluids. Turned wood vessel, with thermometer, and lid bored with hole to admit hot iron cylinder, resting by flange on edge of hole. With different liquids, thermometer took different times to rise 3°; had sides of vessel alone operated, times should have been equal.

Rumford, ib. 14, 353 (1806). Heats water-surface from the point of a cone just dipping into it, and fails to raise the temperature of a thermometer beneath. Admits, however, that thermometer might have been raised, had heated particles of water been prevented from rising up outside of the cone.

Langberg, 'Ph. Mag.' (3), 20, 161 (1846).—Metals, Cu, Steel, Sn and Pb. No thermometers, but thermo-pair applied to surface. Bars (or wires) about 36 mm. long, and 1·7 × 1 mm. section. Law of Biot found not to hold. But ? as to correctness of thermopile indications, from thinness of bars and long contact.

Wiedemann, ib. (4) 10, 393 (1855).—See 'A.C.P.' (3), 45, 377. Longer and more detailed abstract here.

Thomson, ib. (4) 22, 23 and 121 (1861).—Reduction of underground temperature observations, and deduction of K for the rocks in the three Edinburgh stations. See Trans. R.S.E. xxiii. (1860) p. 426, and these Reports (on 'Conductivity') for 1875.

Neumann, ib. 25, 63 (1863).—Translation from 'A.C.P.' (3), 66, 183.

Ångström, ib. 25, 130.—Cf. Pogg. 114, 513, of which this is a translation, fuller than the abstract in 'A.C.P.' (3) 67, 369. In addition to figures for Cu and Fe, deduces from Upsala observations of underground hemperature ('Act. Reg. Soc. Sci. Ups.' S. 3, 1,211) for

Argillaceous sand $\frac{K}{c\delta}$	·26952	. δ...1·725	. c... ·4416	. K... ·2053
Moist clay . .	·27958	. 1·821	. ·4448	. ·2264

Reduced to B.A. units, multiplying by $\frac{\text{sec.}}{\text{min.}}$, we get ·00342 and ·00377 as the values of K.

Gripon, ib. 32, 547 (1866).—Mercury, by Péclet and Despretz' method. Results 1·67 (Pb = 3·84, Péclet); 3·54 (Ag = 100).

Guthrie, ib. 35, 283 (1868).—Liquids: film of liquid sustained by adhesion between two flat plates; one the lower surface of heating steamer, the other the upper surface of 'bulb' of air-thermometer. Order of conductivity only: Hg, water, oil of turpentine, glycerine, amyl iodide, nitro-benzene, aniline.

Paalzow, ib. 36, 469 (1868).—Liquids. Despretz' method, using glass vessel (60 mm. diameter), and four thermometers. Order of conductivity only: Hg, H_2O, Sat. $CuSO_4$, H_2SO_4 (1·25), Sat. $ZnSO_4$, Sat. NaCl.

McFarlane, ib. 43, 392 (1872).—External conductivity (emissive power) of Cu. Ratio of polished to blackened surface, for differences from 5° to 60° C., nearly constant at ·690.

Mayer, ib. 44, 257 (1872).—Application of double iodide of Hg and Cu, which changes colour at 70°C., to determine crystal conductivities after de Senarmont's method.

Weber, ib. 481.—Fe and German silver; used Neumann's modification of Ångström's method, bringing the two ends of a bar alternately for stated periods to temperatures u_0 and u_1, and observing by thermopairs the constant temperature ultimately attained by the middle point, and the difference of temperature between points distant $\frac{1}{6}$ and $\frac{2}{6}$ of the whole length of the bar from one end. These give two relations between h and k (mathematical exposition given in paper) whence values of h and k are deduced.

For Fe, k = ·1485, h = ·000266 (@ 39° C.)
For German silver, k = ·08108, h = ·000304 (@ 31° C.)

Rumford, 'Ph. Trans.' 1804, 23.—Holes in glaciers filled with water, how explained. Reply to Murray's and Thompson's remarks on his former experiments. No experiments.

Hopkins, ib. 1857, 805.—Rocks, 5-in. disc, about $1\frac{1}{2}$ – 2″ thick, surrounded by a square block of substance of similar conductivity, resting in contact with Hg, and having upper surface covered with layer of Hg. Lower Hg heated by steam or otherwise, and when stationary state had supervened, temperatures of lower and upper Hg (taken as those of lower and upper surface of rock) read along with atmospheric temperature. Comparative values of k thus obtained.

Calcareous powder	·056
Argillaceous ,,	·070
Siliceous ,,	·150
50% Arg. and 50% Sil. powder	·110
Chalk, well-dried	·170
Clunch, very wet	·300
Oolites from Ancaster	·38, ·37, ·37
Statuary marble	·53
Blue mountain limestone, Derby	·55
Dry clay	·27
Very dry	·23
Moist	·37
New red sandstone	·25
,, (wet)	·60
Freestone	·33
Building sandstone	·43
Millstone grit (decomp.)	·376
,, grit	·58
Millstone-grit, Dukenfield, 120 ft.	·51
,, ,, deeper	·65
,, ,, 1,300 ft. v. hard	·726
,, ,, Chapel-le-Frith	·75
,, ,, ,,	·76
Blue hard sed. rock Penmaenmawr	·5
,, ,,	·6
Slate, Charnwood Forest	·61
Granite	·53
Scotch granite	·55
'Welsh granite' (so-called)	·60
Scotch large-grained granite	·75
Basalt, L. Katrine	·53
Syenite, Charnwood Forest	·85
Hard close-grained rock do.	·99
Igneous rock, L. Katrine	1·00
Basalt do.	·59
Mountsorrel granite	·80
Spermaceti	·086
Wax	·072

Effect of pressure and temperature on conductivity practically nil. Effect of discontinuity to lessen conductivity, but not to any great extent where good contacts exist between discontinuous portions. Effect of moisture largely to increase conductivity, attaining a maximum before saturation of the rock is reached.

Calvert and Johnson, 'Ph. Trans.' 1858, 349, and 1859, 831.—Metals, alloys, and amalgams. Square bars, with one end immersed in hot, other in cold, water, both of known temperature. Means taken to obviate passage of heat between calorimeters, except through bar, and rise of temperature of cold water in given time noted. Relative results only, and probably only order of conductivity since influence of sp. heat must have been considerable. Long table of resulting figures. Action of compound bars compared with that of alloys.

Guthrie, ib. 1869, 637.—Liquids. Same apparatus as in 'Ph. Mag.' 4, 35, 283, but modified by having cone surfaces of Pt, ground quite plane, and with an arrangement for regulating and measuring distance between. Figures for relative 'resistances' given. No. of ht.-units arrested per minute by 1 sq. dm., 1 mm. thick, T (of air) being 20°·17 C. and Δ T 10° C., as follows :—

Water	·0106	Amyl acetate	·1060
Glycerine	·0407	Amylamine	·1075
Acetic acid	·0888	Amyl alcohol	·1084
Acetone	·0902	Oil of turpentine	·1245
Ethyl oxalate	·0938	Butyl nitrate	·1258
Sperm oil	·0938	Chloroform	·1283
Alcohol	·0963	Bichloride of carbon	·1369
Ethyl acetate	·0963	Mercury amyl	·1369
Nitrobenzol	·1045	Ethylene dibromide	·1395
Amyl oxalate	·1060	Amyl iodide	·1407
Butyl alcohol	·1060	Ethyl iodide	·1505

Thomson, W. 'Camb. Math. Journ.' 3, 25.—Motion of heat in a sphere. 3, 71. Motion of heat in homogeneous solids. 3, 171. Linear motion of heat. 3, 206. Ditto, part 2. 4, 33. Equations of motion of heat referred to curvilinear co-ordinates. 4, 67. Some points in the theory of heat. 4, 179. Orthogonal isothermal surfaces.

Stefan, 'Chem. Soc. Jour.,' 25, 591 (1872).—Gases: Abstract of method. Results for air K = ·000056 (c.g.s.) Conducting power of a gas independent of density. K for hydrogen = seven times K for air.

Mayer, 'Sill. Amer. Jour.' (3) 4, 37 (1872) Cf. 'Ph. Mag.' (4), 44, 257.

Forbes, 'P.R.S.E.' 1, 5 (1833).—Conducting powers of metals for heat and electricity. Order for heat determined by Fourier's contact-thermometer: Au, Ag, Cu, Brass, Fe, Zn, Pt, Sn, Pb, Sb, Bi.

Forbes, ib. 1, 223 (1838).—Results of observation of underground thermometers; and ib. 1, 343 (1841).—Same discussion continued. Order of conductivity. Sandstone, sand, trap, beginning with the best.

Forbes, 'P.R.S.E.' 4, 607 (1862). Conductivity of Fe. Loss of heat at different temperatures by radiation and convection determined directly. Conductivity then calculated for different temperatures; approximate results, K = (c.g.s.) 0°, 206; 50°, ·186; 100°, ·166; 150°, ·1455; 200°, ·127.

Ib. 5, 369 (1865).—Further reductions and observations with the same bars, and also with another of different make.

	1862	1865	1865 (new bar)
0°	·206	·207	·153
50°	·186	·177	·1395
100°	·166	·157	·129
150°	·1455	·145	·123
200°	·127	·136	·118
250°		·128	·114

Tait, ib. 8, 55 (1873).—Note on Ångström's method of determining conductivity, with some approximate determinations.

Forbes, G. ib. 62.—Conductivity of ice and other substances. Rate of formation of plate of ice measured, formed in water of 0° C. by vessel with flat bottom containing freezing mixture. Similar method adopted for other substances. Results (c.g.s.)

Ice, par. to axis	·00223	Kamptulicon	·00011
„ perp. to axis	·00213	Vulc. Caoutchouc	·00009
Black marble	·00177	Horn	·000087
White „	·00115	Beeswax	·000087
Slate	·00081	Felt	·000087
Snow	·00072	Vulcanite	·000080
Cork	·00072	Haircloth	·000040
Glass	·00050	Cotton wool (div.)	·000043
Pasteboard	·00045	„ „ (comp.)	·000033
Carbon	·00040	Flannel	·000035
Roofing felt	·00033	Coarse linen	·000030
Firwood, ax.	·00030	Quartz (par. to ax.)	·00092
„ tang.	·00009	„	·00024
Boiler cement	·00016	„	·00056
Paraffin	·00014	„	·00083
Sand	·00013	„ (perp. to ax.)	·00400
Sawdust	·00012	„	·00442

Figures all very low, save that the one for ice agrees with De la Rive's.
Figures for quartz show conductivity five times as great *across* axis as along it.

Playfair, 'Trans. R.S.E.' 6, 353 (1812).—Cooling of a sphere. Simple mathematical treatment of the question of terrestrial temperature.

Forbes, 'Trans. R.S.E.' 23, 133 (1862) and 24, 73 (1865). c. 'Proc.' 4, 607 and 5, 369. —Details of experimental method and of the calculation of the results.

Helmersen, 'Ann. Chim. Phys.' (3), 46, 126 (1856).—Rocks (from Altai). Despretz' method: bars, 456mm. × 38mm. square; four thermometers 67mm. apart, and holes filled with Hg; bars covered with black to equal surface; hot end in contact with boiling H_2O.

	v_1	v_2	v_3	v_4	K			Average K;[1] relative (assumed absolute) values
	°	°	°	°				
Quartz	12·45	4·8	2·1	1·1	5836	7758	12680	8758 (·00710)
Quartzose mica schist	11·5	4·1	1·7	·7	4984	6841	6734	6186 (·00501)
Fine-grained granite, little mica	8·6	2·4	·8	·3	3255	4393	5511	4386 (·00356)
Wh. fine grnd. marble	8·1	2·1	·85	·4	2909	6481	9331	6240 (·00510)
Porphyry (aphanite with albite)	8·55	2·2	·75	·35	2877	4578	9128	5528 (·00448)
Hard serpentine	7·85	2·15	·95	·45	3161	7948	9496	6868 (·00555)
Fine-grnd. s. stone with argill. cement	8·7	2·3	1·05	·7	2995	8623	32250	5809 (·00471)
Limestone	7·75	2·1	·75	·35	3110	5001	9128	5746 (·00466)

[1] The average values here found differ (as above described in this report) from those entered in the general list, in being obtained from the three *successive* observed thermometric intervals; while those adopted in the list are similarly deduced from the three temperature-intervals all reckoned *from the first*, or hottest of the four thermometric readings v_1–v_4.

L. De la Rive, 'Ann. Chim. Phys.' (4), 1, 504 (1864): also 'Bibl. Univ. de Genèv.' 1864.—Conductivity of ice. Plates of glass, ice, iron, fixed in wooden tube, and interspaces filled with Hg. Outside of glass, H_2O @ 0° C., outside of Fe, cooled turpentine. Thermometer between glass and ice falls, and when it reaches minimum flow across glass = flow across ice, hence $\frac{K\ (\text{ice})}{K\ (\text{glass})}$ obtained 1·76. K (glass) got by Péclet's method, using water at 0° C. and mercury on opposite sides. Results for glass, ·0013, ice, ·0023 (c.g.s). Paper then discusses rate of increase of thickness of ice in a lake. (See Forbes, 'P.R.S.E.' 8, 62.)

Tyndall, 'Ph. Trans.' 1853, 217.—Woods and organic bodies. Comparative results only. Results in 'Heat a mode of motion.'

Despretz, 'Compt. rend.' 7, 833 (1838).—Passage from one solid to another. Cu and Sn fixed end to end (pressed together). Temperature of junction calculated from each bar: Cu thus about 1°·5 hotter.

Despretz, ib. 35, 540 (1852).—New determinations of K for metals, &c. Answer to objections raised by Langberg and others to the former results.

	q
Cast iron	2·0024
Iron	2·017
Statuary marble	2·133
Lithographic stone	2·100
Pierre de Tonnerre	2·302
Pine wood	2·190

Schumeister, 'Chem. Soc. Jour.' 34, 831 (1878).—Conductivity of cotton, wool, and silk. K, (air = 1) for cotton 37, wool 12, silk 11.

Littrow, 'Wien. Ber.' 1875, 4, 'Chem. Soc. Jour.' 28, 1150 (1875).—Soils. Thermometers bedded in the soils at different distances from the source of heat in an india-rubber cylinder. Finely divided soil conducts worse than coarser. Organic matter diminishes conductivity. Wet soils conduct better than dry.

Less, 'Pogg.' Ergänzb. 8.—Rocks and woods. Plate gripped between mercury-wetted copper bottom of steam vessel and mercury-wetted upper surface of equal-sized blackened Cu plate. When stationary state of things reached, thermopile exposed to radiation from Cu plate, and deflections give relative conductivity.

A Supplementary List of Original Notices and Memoirs on Subjects relating to Conduction of Heat. By J. T. Dunn.

'Comptes Rendus.'

Author	Reference		Nature of contents
Henwood	vol. 1	p. 343	Temperature in mines.
Liouville	3	622	Mathematical
,,	3	653	,,
Despretz	7	833	Junction of two solids
,,	7	933	Liquids
Péclet	8	627	
Despretz	8	838	Liquids
,,	8	879	,,
Senarmont	25	459	
,,	25	707	
Duhamel	25	870	Mathematical
Desains	26	212	'Diffusion of heat'
Masson and Jamin	31	14	,, ,,
Desains	33	444	,, ,,
Despretz	35	540	
Gouillaud	35	699	Metals
Jamin	36	994	
Duhamel	43	1	Mathematical
Calvert and Johnson	47	1069	

'Comptes Rendus.'

Author	Reference		Nature of contents
Morin	vol. 61	p. 477	Mathematical
Gripon	63	21	Mercury
Morin	66	1332	Mathematical
Calvert and Johnson	68	192	Alloys of Cu and Sn
Boussinesq	69	329	Mathematical
Jamin and Richard	75	105	'Refroidissement des gas'
" "	75	453	" "
Jannettaz	75	940	Crystals
"	75	1501	"

'Ann. Sci. Lomb. Veneto.'

Fusiniere	2	141	Conduction in a bar

'Turin Mem. Acad.'

Senebier	1804	51	

'Jour. des Mines.'

Biot	17	203	

'Moniteur Scient.'

Despretz	13	254	Two superposed liquids

'Paris Mém. Acad. Sci.'

Cordier	7	473	Terrestrial temperature

'Genèv. Mém. Soc. Phys.'

Decandolle	4	70	Woods

'Moigno. Cosmos.'

Despretz	1	706	

'Paris École Polyt. Jour.'

Duhamel	13	356	Mathematical
"	14	20, 67	"
Lamé	14	194	

Liouville, 'Journ. Math.'

Duhamel	4	63	Mathematical
Lamé	2	147	"
Liouville	13	72	"

Gergonne, 'Ann. Math.'

Liouville	21	133	Mathematical

'Mém. Sav. Étrang.'

Lamé	5	174	
"	5	418	

'L'Institut.'

Thomas and Laurens	1	7	

'St. Pétersb. Acad. Sci. Mém.'

Ostrogradsky	1	123	Mathematical
"	3	353	"
Lenz	14	54	Temperature and conductivity of metals

Quetelet, 'Corresp. Math.'

Pagani	3	237	Mathematical
"	4	384	"

'Arch. Sci. Phys. Nat.'

Ångström	22	321	

'Gilbert's Annals.'

Rumford	1	214	Fluids
"	2	249	"
Deluc	1	464	"

Author	Reference		Nature of contents
	'London Elect. Soc. Proc.'		
Pollock (1843)	vol. 9	p. 66	
	Sturgeon, 'Ann. Elec.'		
Schröder (1839)	5	104	
	'Manch. Lit. and Phil.'		
Calvert (1860)	2	165	Amalgams
	'Manch. Phil. Soc. Mem.'		
Dalton (1802)	5	373	Fluids
	'Proc. Roy. Soc. Edin.'		
Forbes	1	223	Edinburgh earth-thermometers.
"	1	343	Edinburgh earth-thermometers.
"	4	607	Iron
"	5	369	Conduction in a bar
" Geo.	8	62	Ice, &c.
	'Trans. Roy. Soc. Edin.'		
Playfair (1812)	6	353	Conduction in a sphere
Forbes	24	73	Conduction in a bar
	'Quart. Journ. Sci.'		
Fox (1822)	12	339	Terrestrial temperature
	'Glasgow Phil. Proc.'		
Gordon (1844)	2	140	Terrestrial temperature
	'Edinburgh Journal of Science' and 'New Phil. Jour.'		
Henwood (1829)	'E.J.S.' 10	323	Temperature in mines
" (1861)	'E.N.Ph.J.' 13	173	" in Chilian do
	'Cornwall Geol. Soc. Trans.'		
Henwood (1843)	5	246	Temperature in Cornish mines
	'Gehlen. Jour.'		
Senebier	7	307	
	'Berlin Akad. Ber.'		
Langberg	1845	268	
Magnus	1868	158	
"	1868	249	
	'Wien. Akad. Ber.'		
Stefan	47	326	
"	65	45	Gases
	'Deut. Chem. Ges. Ber.'		
Mohr	4	85	Gases
Clausius	4	269	"
	'Bull. Géol. Soc. Paris.'		
Jannettaz	1873	117	Crystals
	'Crelle Jour.'		
Amsler	42	327	
	'Paris, Bureau Long. Ann.'		
Arago	1834	171	Terrestrial temperature
	'Bibl. Univ.'		
Anon (1816)	3	77	Experiments relative to transmission of heat
Arago	4	165	Terrestrial temperature
Schröder	19	162	
	'Journ. de Phys.'		
Aubuisson de Voisins	62	443	Terrestrial temperature

Author	Reference		Nature of contents
	'Paris Soc. Philom Bull.'		
Biot	1801	p. 36	Fluids
,,	1804	215	
,,	1815	21	Newton's law
Dupretz (? Despretz)	1821	113	Solids
	'Upsal. Nov. Act. Soc. Sci.'		
Ångström	1	147	Terrestrial temperature
,,	3	51	
	'Stockholm Ofversicht.'		
Ångström	18	3	
,,	19	21	
	'Poggendorff.'		
Fischer	(1830)	507	Platinum
Schröder	46	135	?
Despretz	46	484	Junction of two solids
Péclet	55	167	
Langberg	66	1	
Müller	73	474	Heat or electricity ?
Desains	74	147	?
Wiedemann & Franz	89	497	Metals
Wiedemann	95	337	,,
,,	108	393	Alloys
Pfaff	113	647	Crystals
Ångström	114	512	Metals
Clausius	115	1	Gases
Ångström	118	423	
,,	123	628	
Magnus	134	45	
Kirchhoff	134	177	Conductivity and sound
Paalzow	134	618	Fluids
Despretz	142	626	Two superposed fluids
Weber	146	257	Iron and German silver
Beetz	Jubel	23	Gases
Hermann	151	177	Mercury

Report of the Committee, consisting of Mr. JAMES HEYWOOD, *F.R.S.*, Mr. WILLIAM SHAEN, Mr. STEPHEN BOURNE, Mr. ROBERT WILKINSON, the Rev. W. DELANY, Prof. N. STORY MASKELYNE, *M.P.*, *F.R.S.*, Dr. SILVANUS P. THOMPSON, Miss LYDIA E. BECKER, Sir JOHN LUBBOCK, *Bart.*, *M.P.*, *F.R.S.*, Professor A. W. WILLIAMSON, *F.R.S.*, Mrs. AUGUSTA WEBSTER, *and* Dr. J. H. GLADSTONE, *F.R.S.*, (*Secretary*), *on the manner in which Rudimentary Science should be taught, and how examinations should be held therein, in Elementary Schools.*

YOUR Committee, as constituted at Swansea, believed that it would be very desirable to add to their number Sir John Lubbock, Bart., Professor Williamson, F.R.S., and Mrs. Augusta Webster, Member of the London School Board, each of whom is well known to have taken a deep interest in the subject for which the Committee was appointed. Each of these acceded to the request, and the Committee, so constituted, present the following report.

Rudimentary science is taught in public elementary schools in the form of—I. Object lessons. II. Class subjects under article 19, c. 1, of the New Code. III. Specific subjects under Schedule IV. of the same

Code. IV. Science subjects preparatory to entering classes in connection with science schools.

I. Object lessons are attempted in a large number of infant schools, and in some instances are very effective in developing the perceptive powers and intelligence of the children; but in other cases they are too formal, and left too much to the junior teachers. In boys' and girls' schools they frequently appear upon the time-table, especially where, as in the schools of the London Board, they are looked upon as a necessary part of the instruction: but they are generally given in an unsystematic, and often in an unsatisfactory manner.

II. The teaching of science as a class subject under the Code only commenced last October, and thus no examinations have yet been held under it. Natural history, physical geography, natural philosophy, &c., are mentioned in article 19, c. 1, and it is stated that the instruction should be given 'through reading lessons, illustrated, if necessary, by maps, diagrams, specimens, &c.;' but the teachers are limited to two subjects, and the old subjects, grammar, history, geography and needle-work, naturally retain their place in the great majority of the schools. Suitable reading-books for these rudimentary science subjects have scarcely yet come into existence.

III. The specific subjects of the fourth schedule include mechanics, animal physiology, physical geography, botany, and domestic economy, but only two subjects may be taken (or three if the child has passed Standard VI.); and the schedule also includes English literature, mathematics, Latin, French, and German. Literature is a general favourite; and domestic economy is obligatory in girls' schools if any specific subject is taken at all; so that the chance of any of the others being introduced is very much diminished. It must also be remembered that these subjects are only allowed to be taught to children in the fourth standard and upwards; while only about one-fifth of the children in the boys' and girls' schools are to be found at present in these standards. According to the Report of the Committee of Council for Education recently issued, there were 476,761 children presented for examination in these standards, of whom the following numbers only were examined in the science subjects:—

Mechanics	2,109
Animal physiology	24,725
Physical geography	34,288
Botany	1,853
Domestic economy	50,797

Out of 489 boys' and girls' departments under the London School Board, the specific science subjects were taken up, as follows, during the year 1880:—

Mechanics in	4	departments
Animal physiology in	123	,,
Physical geography in	112	,,
Botany in	9	,,
Domestic economy in	172	,,

Mr. Hance, of the Liverpool School Board, has favoured us with an account of the systematic scientific instruction which is given in the Board schools of that town by a special science staff. The subject selected for the boys is mechanics as defined in the new code, with a considerable development in the direction of elementary physics. It has been in operation since 1877, and the results for the year 1880–81 are given in the following table:—

Year 1880–81.	Number presented	Number passed	Percentage of passes
Stage I.	797	442	55·46
„ II. . . .	398	261	65·59
„ III. . . .	122	82	67·21
Total	1317	785	59·6

Domestic economy is also taught to the girls in a similar manner.

In Birmingham 1200 scholars are receiving scientific instruction in the schools of the Board, and it is stated that the teachers uniformly find that 'it added interest to the work of the school, that the children were eager to be present, and that the lessons were enjoyed, and were in fact giving new life to the schools.' The Board have found the results so satisfactory that they are now furnishing their newest school with a laboratory and lecture-room.

IV. As to science-teaching which does not fall under the provisions of the New Code it is not probable that any large amount is attempted. In Manchester, however, the Board gives instruction to 404 children, all of whom have passed Standard VI., the highest ordinary standard, in the following subjects:—

Physiology.
Acoustics, Light and heat,
Magnetism and electricity.
Chemistry
„ practical.
Botany.

This teaching is illustrated by means of good apparatus, &c., and has had a very beneficial effect upon the science and art classes of the town.

When it is considered that the provisions of the Code naturally form, in almost all cases, the extreme limit of what will be attempted in the schools, it is important that they should be placed as high as possible. This will be a great advantage to the stronger schools, and no disadvantage to the weaker ones, as the higher branches of science-teaching will of course be optional.

Your Committee have, therefore, arrived at the following conclusions:—

I. *As to object lessons.* That it is very desirable that Her Majesty's Inspectors should take object lessons into account in estimating the teaching given in an infant school; and that they should examine the classes in the graded schools wherever object lessons are given.

II. *As to class subjects.* That the teaching of such subjects as natural history, physical geography, natural philosophy, &c., should not necessarily be 'through reading lessons,' as oral lessons 'illustrated by maps, diagrams, specimens, &c.' are undoubtedly better when given by a teacher duly qualified to handle these subjects. They are of opinion, also, that it will be desirable to allow a larger number of class subjects to be taken up in any particular school, and to give in such case a proportionately increased grant.

III. *As to specific science subjects.* That a knowledge of the facts of nature is an essential part of the education of every child, and that it should be given continuously during the whole of school life from the baby class to the highest standard. Of course in early years this teaching will be very rudimentary; but by developing the child's powers of perception and comparison it will prepare it for a gradual extension of such knowledge. They consider also that the early teaching must be very general, while the later may be more specific; they think, however, that the science subjects as given in Schedule IV. are fairly open to objection, as being somewhat too ambitious in their nomenclature and in their scope, and that they ought not to be attempted unless the child has had a previous training in natural knowledge before entering the fourth standard. Thus the specific scientific subjects ought not to be distinct, as they practically are at present, from the previous teaching; greater latitude of choice might be allowed in them; and while they should not afford technical instruction they should prepare the way for any technical classes or schools into which the children may subsequently enter. In regard to domestic economy they are of opinion that most of the points embraced in the schedule would be useful to boys as well as to girls.

IV. *As to examinations.* That in the appointment of Her Majesty's Inspectors some knowledge of natural science should be considered as absolutely requisite; that in examining the children they should direct their inquiries so as to elicit not so much their knowledge of special facts as their intelligent acquaintance with the world of nature around them; and that this may be much better done by oral examination than by paper work.

Postscript.—Since this report was in the printer's hands, Mr. Mundella, the Vice-President of the Committee of Council on Education, has laid upon the table of the House of Commons certain proposals for revision of the Code. Your Committee is very glad to observe that these proposed changes are generally in the direction indicated in the above recommendations. Thus, in Infant Schools the full grant will not be paid unless there be provided 'a systematic course of simple lessons on objects, and on the phenomena of nature, and of common life;' the children in Standard I. may share in the benefit of elementary science teaching; and the instruction of the children in the subsequent standards in scientific subjects need not necessarily be given 'through reading lessons.' Your Committee regrets that a stronger inducement has not been held out to introduce rudimentary science as a class subject; or rather, that the prominence given to English grammar and the recitation of poetry will exclude the new lessons on elementary science from schools where geography continues to be taken up. It is to be feared, indeed, that if these proposals should be adopted in their present shape, the children of Standard IV. will have even less chance of instruction in natural knowledge than they have at present, for they will not be allowed to take up any science as a specific subject, while their taking elementary science as a class subject will be very problematical. Your Committee, therefore, while expressing great satisfaction with the general scope of these proposals, would urge that the knowledge of nature be put on an equal footing in our schools with the analysis of the mother tongue, and that any two of the proposed three class subjects may be taken.

Third Report of the Committee, consisting of Professor W. C. Williamson *and* Mr. W. H. Baily, *appointed for the purpose of investigating the Tertiary Flora of the North of Ireland. Drawn up by* William Hellier Baily, *F.L.S., F.G.S., M.R.I.A. (Secretary).*

[Plates I. & II.]

The present Report is an account of the continuation of work conducted by the Secretary, the results of which have been laid before the British Association at their last and a previous meeting.

The still further opening up of the iron ore deposits in the County of Antrim has enabled us to continue the investigation of the plant-remains associated with it.

By the identification of these plant-remains we are enabled to fix the period at which they lived as being Lower Miocene, and thus to determine the age of the great flow of basalt which is estimated at fifty miles long by thirty wide, and consequently to extend over about 1,200 square miles of the north of Ireland, attaining in some places a thickness of 900 feet. They also afford strong evidence of being contemporaneous with other volcanic districts, such as those of the island of Mull, on the west coast of Scotland, and North Greenland, where mid-European plants, such as these, once flourished.

Most abundant amongst these plant-remains in the North of Ireland is the sequoia, a species of cypress allied to the great Wellingtonia—*Sequoia sempervirens* and *S. gigantea* of California. The species from these deposits is closely allied to the fossil *Sequoia Langsdorfi*, but has been considered sufficiently distinct to receive the specific designation of *Sequoia Du Noyeri*. Another species from the ironstone nodules found on the shores of Lough Neagh is evidently identical with *Sequoia Couttsiæ*, common at Bovey Tracey, also occurring on the Baltic shores and at North Greenland.

Impressions of what appear to be the cones of Sequoia and other fruits are not unfrequent in the sedimentary ochreous deposits of Ballypalady, and at the same place are masses of wood, evidently coniferous, which may probably have belonged to the Sequoia.

Mr. Walter Jamieson, manager of the Eglinton Company of Glasgow's Mining Works at Glenarm, has kindly furnished us with much valuable information respecting the Miocene deposit there, which is worked by that company in connection with the aluminiferous earth or bauxite, and contains an abundance of plant-remains from which on our various visits we have obtained many interesting specimens. He estimates these deposits, under the Upper Basalt, at not less than 50 or 60 feet in thickness, and states that at Cullinane, near Glenarm, in the course of the mining operations carried out under his direction, he had been fortunate enough to find upwards of twenty specimens of fossilised wood of large size. One of these deserves special mention, as being the root and about five to six inches of the erect stem of a tree which was found under about 50 feet of basalt. He describes it as 'having a decidedly charred appearance, its upper portion being in immediate contact with the basalt, and the stem and root imbedded, to their full extent, in the aluminous clay.' On a recent visit to Glenarm, this gentleman exhibited to us fragments of several of these large trunks of trees which he had collected, some showing knots. One of these pieces of wood measured in its flattened state 20 inches across; its diameter would probably have been about six feet in an uncompressed state. These large woody trunks were found lying at various angles in the aluminous earth. The character of this wood still remains to be determined.

Branches of a cypress, and pine cones, with grasses and reed-like plants, are not unfrequent in these deposits.

Leaves and seeds or fruit of Dicotyledonous trees are most frequent. We have been enabled to identify several of these with fossil plants from the island of Mull, Œningen, and North Greenland.

A list of all the species named and identified to the present time is appended to this report; and as there are others we have, for want of sufficient material, only been able to name generically, it may be thought desirable to continue this investigation, which has added so largely to our hitherto meagre Miocene Flora of the British Islands.

LIST OF SPECIES.—NORTH OF IRELAND.

CRYPTOGAMÆ. *Fungi.*	
Sphæria concentrica (Mass.) Flor. Senégalliese	Sandy Bay, Lough Neagh.
Filices.	
Hemitelites Frazeri (Baily) B. A. Report, 1879	,, ,,
CONIFERÆ. Order *Cupressinæ.*	
Cupressoxylon Pritchardi, Silicified Wood	Shores of Lough Neagh, &c.
Cupressites McHenrici (Baily), 'Journ. Geol. Soc.' vol. xxv. pl. 15, fig. 5	Ballypalady, Co. Antrim.
Taxodium sp.	,, ,,
Order *Abietinæ.*	
Sequoia Du Noyeri (Baily), 'Journ. Geol. Soc.' vol. xxv. pl. 15, fig. 4	Ballypalady and Glenarm.
Sequoia Couttsiæ (Heer)	Sandy Bay, Bovey Tracey, N. Greenland, Baltic Shores.
Pinus Plutoni (Baily), 'Journ. Geol. Soc.' vol. xxv. pl. 15, fig. 1	Ballypalady.
Pinus Graingeri (Baily), 'B. A. Rep.' 1880, pl. 2, fig. 3	,,
Fam. *Taxinæ.*	
Torellia rigida (Heer)	,, and Spitzbergen.
MONOCOTYLEDONES.	
Fam. *Gramineæ.*	
Phragmites Œningensis (Ad. Brong.)	Ballypalady; Œningen, N. Greenland, Spitzbergen.
,, sp.	Ballypalady.
Poacites sp.	,,
Iridæ.	
Iris latifolia? (Heer)	,, Spitz. Baltic.
DICOTYLEDONES.	
Fam. *Salicinæ.*	
Salix sp.	Ballypalady.
Populus sp.	,,
Betulaceæ.	
Alnus Kefersteini? (Goepp.)	,, and Baltic.
Cupuliferæ.	
Corylus McQuarrii (Forbes)	Lough Neagh, Island of Mull, & North Greenland.
,, sp.	Lough Neagh and Glenarm.
? Fagus sp.	Ballypalady.
Quercus sp.	Glenarm.
Moreæ.	
Platanus Guillelmæ (Goepp.)	Glenarm, Œningen, and North Greenland.

Laurineæ.	
? Sassafras sp.	Glenarm.
Aceraceæ.	
Acer sp.	„
Ericaceæ.	
Andromeda sp.	Ballypalady.
Caprifoliaceæ.	
Viburnum Whymperi (Heer)	Ballypalady, Spitzbergen, and N. Greenland.
Araliaceæ.	
Aralia Browniana (Heer)	Lough Neagh and N. Greenland.
Nyssa ornithobroma (Heer), 'B. A. Report,' 1880, pl. 2, fig. 7, *a b*	Glenalvy River, Lough Neagh and N. Greenland.
Magnoliaceæ.	
Magnolia glauca ? (Heer)	Ballypalady and N. Greenland.
Menispermaceæ ?	
McClintockia Lyalli (Heer)	Glenarm and N. Greenland.
„ trinervis (Heer)	Glenarm, Ballypalady and North Greenland.
Rhamneæ.	
Rhamnus sp.	Ballypalady and Glenarm.
Juglandeæ.	
Juglans acuminata ? (A. Braun)	Ballypalady, Œningen, and N. Greenland.

Other leaves are at present undetermined; some of them apparently belong to Ficus, Myrica, Cinnamonium, Olea, Fraxinus, Laurus, &c.

In Messrs. Tate and Holden's communication to the Geological Society of London on iron ores associated with the basalts of the N.E. of Ireland, 'Quart. Journ. Geol. Soc.' vol. xxvi. pp. 151, &c., the following additional identifications are given on their authority :—' Platanus aceroides, Sequoia Langsdorfi, species of Juglans, Fagus, Laurus, &c., from ash-beds on the shores of Lough Neagh, and from the sedimentary ochreous beds at Ballypalady we have collected the following unrecorded forms :—Eucalyptus oceanica, Ung. Hakea sp., Celastrus sp. Daphnogene Kanii, Heer ? Graminites, sp. &c.'

Explanation of the Plates.

Plate I.

Fig. 1. Phragmites sp.
„ 2. Alnus (allied to A. gracilis) } In ironstone, from near Glen Conway, bed of
„ 3. Nyssa ornithobroma (seed) } Glenavy river, Lough Neagh. Collection of Rev. Canon Grainger, D.D.
„ 4. McClintockia trinervis (Heer), Ballypalady. Collection of Nat. Hist. Museum of Science and Art, Dublin.
„ 5. Ficus sp., allied to F. lanceolata (Heer), Flor. Mioc. Balt. pl. 22, figs. 1, 2. Ballypalady. Coll. Nat. Hist. Mus. Science and Art, Dublin.
„ 6. *a*, *b*. Fruit ? allied to Sparganium stygium (Heer), Foss. Flor. of N. Greenland. 'Phil. Trans.' pl. 42, figs. 4, 5.

Plate II.

Fig. 1. Quercus sp., showing reticulated structure, Glenarm.
„ 2. Alnus Kefersteinii ? (Goepp.), Flor. Mioc. Balt. pl. 19, figs. 1–13, Glenarm.
„ 3. Platanus Guillelmæ ? (Goepp.), Foss. Flor. N. Greenland, pl. 59, fig. 4 *b*, Glenarm.
„ 4. Sassafras ? sp., allied to S. Ferretianum (Massalonga), Foss. Flor. N. Greenland, pl. 50, figs. 1, 2, Glenarm.

W.H.B. Forster & Co. Lith. Dublin.

Illustrating the Report on the Tertiary (Miocene) Flora &c, of the Basalt of the North of Ireland

W.H.B. Forster & Co. Lith. Dublin.

Illustrating the Report on the Tertiary (Miocene) Flora &c. of the Basalt of the North of Ireland

Report of the Committee, consisting of Dr. J. H. Gladstone, Dr. W. R. E. Hodgkinson, Mr. W. Carleton Williams, *and* Dr. P. P. Bedson (*Secretary*), *appointed for the purpose of investigating the Method of Determining the Specific Refraction of Solids from their Solutions.*

The specific refraction of a substance, *i.e.*, the index of refraction, minus unity divided by the density, is, according to Messrs. Gladstone and Dale, a property uninfluenced by the passage from the solid to the liquid state. Further, since the specific refraction of a mixture of liquids is the mean of those of its constituents, it follows that the specific refraction of a solid may be deduced from that of a solution containing it; the specific refraction of the solvent being known. In support of the method of determining the specific refraction of a solid, based upon these observations, these authors have advanced some direct proof ('Phil. Trans.,' 1869, pp. 13, 14), and also a large amount of collateral evidence.[1] The method has, however, been called in question, more especially by Janovsky (Sitzungsber. Wien. 'Akademie,' lxxxii. 1880, 148), who denies the possibility of determining the refractive index of a solid from solution. Hence it was thought desirable to submit the method to further examination, (1) to test the accuracy of the statement made by this investigator, and (2) to ascertain how far this method is applicable to determine the specific and molecular refraction of solid compounds.

In order to test the method, the specific refraction of liquid phenol has been determined and compared with that obtained from its solution in alcohol and glacial acetic acid. Further, the specific refractions of rock salt, borax, and boric acid in the solid state have been compared with the values obtained from their aqueous solutions. The instrument used to determine the refractive indices was a spectrometer obtained from Becker (Meyerstein's successor); its graduated circle is divided into tenths of a degree, and by means of verniers these divisions are further divided, so that readings can be made to one second. The refractive indices have been determined for the hydrogen lines α, β, and γ, in some cases for the sodium line also; from these, by the aid of Cauchy's formula, the index of refraction (A) for a ray of light of infinite wave-length has been calculated. The refractive indices are deduced from at least four readings; the refractive indices, calculated in two sets of observations from such readings, differing from one another in the fifth place of decimals only.

In the case of liquids, a hollow prism was used of about 15 ccm. capacity, closed by two plates of glass, the surfaces of which were parallel. The prism has an aperture for the insertion of a thermometer, by means of which the temperature of the liquid under experiment may be ascertained. The thermometer used was one of Geissler's, graduated to two-tenths of a degree, and, consequently, readings to one-tenth of a degree could be made with accuracy. The temperature of the liquid in the prism was raised to and maintained at the point desired, by means of the circulation of warm water through a series of glass tubes placed at the back of the prism and under the table upon which it stood.

The specific gravities of liquids and solutions were determined in an

[1] Dr. Gladstone's article, *Phil. Mag.*, 1881, pp. 54–60.

apparatus similar in form to that used by Sprengel, by means of which great accuracy can be attained. The specific gravities are given in relation to water at 4°.

The specific refractions of the alcohol, glacial acetic acid, and the distilled water used in the following experiments were determined with special care, and gave the following results:—

	Ref. in. for A	Spec. grav.	$\frac{A-1}{d}$
Alcohol at 20° C	1·35157	0·8019	·4384
„ at 25° C	1·34954	0·7976	·4382
Acetic Acid at 20°	1·36389	1·0559	·3438
Water at 20°	1·32402	0·99831	·3246

I. *Liquid phenol, and phenol in alcoholic and acetic acid solutions.*

The phenol used in these experiments was pure, as ascertained by its boiling point. The values obtained for the specific refraction of liquid phenol at 40° and 45°, viz., ·4850 and ·4848, are closely approximate to that obtained by Brühl ('Journ. Chem. Soc.,' abst., 1880, p. 782) for phenol at 20°, viz., ·4862. Further, these results agree very well with the mean of the specific refractions obtained from the alcoholic and acetic acid solutions.

The following table contains the numbers obtained; the specific gravities were taken at the temperature of observation, water at 4° being taken as unit:—

Description of substance	Temp. of Observation	Spec. grav. H_2O at 4° = 1	α	β	γ	A	$\frac{A-1}{d}$ For phenol
Liquid Phenol	40°	1·0591	1·53618	1·55496	—	1·51375	·4850
	45°	1·0545	1·53386	1·55263	—	1·51144	·4848
Alcoholic solution I. 20·64 % Phenol	20°	0·8540	1·39212	1·40036	1·40534	1·38186	·4801
	25°	0·8487	1·39003	1·39841	1·40317	1·37984	·4828
II. 34·84 % Phenol	20°	0·887	1·41584	1·42578	1·43147	1·40371	·4854
	25°	0·883	1·41371	1·42348	1·42952	1·40144	·4856
III. 48·85 % Phenol	20°	0·9213	1·43680	1·44827	1·45523	1·42247	·4799
Acetic acid solution IV. 25·38 % Phenol	20°	1·0594	1·41585	1·42572	1·43159	1·403612	·4900
V. 36·47 % „	20°	1·0617	1·43498	1·44613	1·45291	1·421039	·4883

Experiments made with phenyl ether (Ph_2O) yielded results similar to those obtained with phenol. The refractive index for Fraunhofer's line A of liquid phenyl ether at 24° was found to be 1·5702, and its specific gravity at the same temperature was found to be 1·0744; hence its specific refraction for this ray is ·5307. An alcoholic solution, containing 50·6 per cent. of phenyl ether, gave ·5265 as the specific refraction for the same line A.

II. *Rock salt in solid state and in aqueous solution.*

Rock salt was chosen for these experiments for the following reasons:—(1) the fact that it can be obtained in large transparent masses, (2) its refraction is not influenced by its crystalline form, (3) its easy solubility in water. For the determination of its refractive index a prism was cut from a piece of a colourless and clear specimen; and the prism then ground and polished. The angle of the prism was determined by aid of the image of the illuminated slit reflected from the two faces, and the refractive indices for α, β, and γ determined in the usual manner. The specific gravity of the prism was determined by weighing it first in air, and then in pure benzene. In the preparation of the aqueous solutions, portions of the rock salt from which the prism had been cut were used. The following table contains the numbers obtained, and the specific refractions of salt for A:—

Description of substance	Temp. of Observation	Spec grav. H_2O at 4° = 1	α	β	γ	A	$\frac{A-1}{d}$ For rock salt
Rock salt . . .	15°	2·1641	1·54095	1·55384	1·56128	1·52515	·2426
Aqueous solution. I. 13·625 % salt . .	20°	1·0979	1·35488	1·36711	—	1·34652	·2587
II. 12·02 % salt . .	20°	1·087	1·35208	1·35881	1·36244	1·34402	·2570
III. 16·88 % salt .	20°	1·108	1·35728	1·36422	1·36805	1·34891	·2415

The specific refraction deduced from the aqueous solution, taking the mean of (I.), (II.), and (III.), is greater by ·0098 than the value obtained for the solid directly. Further, the results from (I.), (II.), and (III.) do not exhibit such agreement amongst themselves as was found in the case of phenol, the extreme difference being ·0172.

III. *Fused borax in the solid state and in aqueous solution.*

Fused borax is one of the few soluble substances which can be easily obtained in large transparent masses. After many futile attempts, it was at last found possible to obtain it in the form of prisms. This end was attained by casting liquid borax, which had been maintained in a state of fusion for a considerable time (in order to remove the air-bubbles), in a mould made of silver plates. The most successful experiments were made with borax which, before pouring into the mould, had been allowed to cool down, so as to render it comparatively viscous. The prisms so obtained were, after annealing, ground and polished. The refractive indices of three such prisms have been determined; their specific gravities were determined as in the case of rock salt. The borax used in the preparations of the aqueous solutions was a portion of the same used to make the prisms. The following table contains the numbers obtained:—

Description of substance	Temp. of Observation	Spec. grav. H_2O at $4° = 0$	α	β	Na line D	A	$\frac{A-1}{d}$ For borax
Borax Prism (1) . .	18·5°	2·373	1·51537	1·52139	1·51323	1·50325	·2120
„ „ (2) . .	16°	2·368	1·51222	1·52068	1·51484	1·50187	·2118
„ „ (3) . .	14·2°	2·370[1]	1·51398	1·52269	1·51615	1·50332	·2124
Aqueous solution			α	β	γ		
(1) 2·423 % borax .	20°	1·0209	1·33589	1·34188	1·34506	1·32876	·2187
(2) 3·653 % borax .	20°	1·0331	1·33819	1·34417	1·34738	1·33104	·2121
(3) 2·077 % borax .	20°	1·0185	1·33520	1·34110	1·34453	1·32795	·2013
(4) 2·504 % borax .	20°	1·0222	1·336025	1·34195	1·345005	1·32904	·2168
(5) 2·405 % borax .	20°	1·0203	1·33655	1·34161	1·34511	1·32816	·2074

The results for the prisms of borax agree very well with one another, the greatest difference being ·0006, and the mean ·2120 may therefore be taken as the specific refraction of fused borax. The mean of the values obtained for borax dissolved in water is ·2112, which differs from the value obtained for the solid by ·0008; the greatest difference, however, exhibited by these numbers being ·0174.

IV. *Fused boric acid in the solid state and in solution.*

Prisms of boric acid were cast in a similar manner to those of borax; and their refractive indices and specific gravities determined in the same manner. The aqueous solutions were prepared with portions of the boric acid used to make the prisms.

The results obtained are contained in the following table:—

Description of substance	Temp. of Observation	Spec. grav. H_2O at $4° = 1$	α	β	Na line D	A	$\frac{A-1}{d}$ For boric acid
Prism of boric acid (1)	14·4°	1·848	1·46220	1·46860	1·46303	1·45437	·2458
2nd Prism . . .	15·8°	1·853	1·46245	1·47024	1·46427	1·45292	·2444
Aqueous solution			α	β	γ		
(1) 1·93 % boric acid .	20°	1·0111	1·33345	1·33938	1·34250	1·32641	·2383
(2) 1·932 % „ .	20°	1·0109	1·33349	1·33937	1·34255	1·32642	·2383
(3) 1·68 % „ .	20°	1·0096	1·33365	1·33958	1·34277	1·32656	·2560

Comparing the mean of the specific refractions of the two prisms, viz., ·2451, with the mean of the values obtained for boric acid dissolved in water, viz., ·2442, the latter is seen to be ·0009 greater in the former.

[1] This specific gravity is the mean of the determinations for the other two prisms.

Here again, as in the case of salt and borax, the extreme difference between specific refractions obtained by the second method is a number affecting the second place of decimals, viz., ·0177.

V. *Fused sodium metaphosphate in the solid state and in solution.*

The attempts made to determine the specific refraction of solid sodium metaphosphate, by a method similar to that adopted in the case of borax and boric acid, were frustrated by the hygroscopic nature of this substance, which rendered it impossible to polish the prisms, which were cast as before. Nevertheless, a close approximation to its refractive index, for a ray of light of infinite wave-length, has been attained, by a method which, by a more careful application, will probably yield exact results. This method consists in making a mixture of two liquids, one more and the other less refractive than the solid, until there is no apparent difference between the refraction of the solid and liquid. The refractive index of the liquid is then determined for α, β, and γ, and the refractive index (A), for a ray of light of infinite wave-length, calculated from these.

Such a mixture of aniline and amyl alcohol gave 1·47518 for A, and one of bromobenzene and amyl alcohol gave 1·45747 for A. The specific gravity of sodium metaphosphate (fused) was found to be 2·503. Hence its specific refraction is ·1898, calculated from the first value of A, and ·1827 from the second. The mean of these values, viz., ·1862, differs by ·0023 from the mean of the specific refractions deduced from its aqueous solution.

The following table contains the results obtained from aqueous solutions of sodium metaphosphate of different strengths:—

Percentage of $NaPo_3$ (fused)	Temp. of Observation	Spec. grav. H_2O at $4^\circ = 1$	α	β	γ	A	$\frac{A-1}{d}$ For $NaPo_3$
5·366 %	20°	1·0412	1·33721	1·34317	1·34637	1·330115	·1826
4·01 %	20°	1·029	1·33570	1·34169	1·34513	1·32847	·1894
8·769 %	20°	1·0673	1·34135	1·34738	1·35076	1·33403	·1919
8·509 %	20°	1·0652	1·34104	1·34705	1·35070	1·33359	·1901
					Mean .	. .	·1885

The extreme difference in the values of $\frac{A-1}{d}$ is ·0093, about the same difference as observed in other cases.

The results of these experiments serve to substantiate the statement of Messrs. Gladstone and Dale, at any rate, as far as singly-refractive solids are concerned. By the aid of the method[1] used to determine the refractive index of solid sodium metaphosphate, some clue will, it is to be hoped, be obtained, as to how far this statement affects doubly-refractive solids.

[1] The mean of two determinations of the specific refraction of rock salt by this method was found to be ·2374; and the mean of two determinations for borax gave ·2108, values differing but slightly from those obtained for solid rock salt and borax.

Fourth Report of the Committee, consisting of Professor Sir WILLIAM THOMSON, Dr. J. MERRIFIELD, Professor OSBORNE REYNOLDS, Captain DOUGLAS GALTON, Mr. J. N. SHOOLBRED (*Secretary*), Mr. J. F. DEACON, *and* Mr. ROGERS FIELD, *appointed for the purpose of obtaining information respecting the Phenomena of the Stationary Tides in the English Channel and in the North Sea; and of representing to the Government of Portugal and the Governor of Madeira that, in the opinion of the British Association, Tidal Observations at Madeira or other islands in the North Atlantic Ocean would be very valuable, with a view to the advancement of our knowledge of the Tides in the Atlantic Ocean.*

YOUR Committee consider that the special works for which they were appointed have been carried out.

In this, their final report, they beg to mention that the pamphlet-notice of the tidal observations, named in last year's Report as having been prepared for those Continental observers who rendered valuable assistance to the Committee in obtaining a portion of the observations, has been circulated.

It appears to be considered to contain valuable information, and as forming the basis, or starting point for common action in the future; when the subject of the phenomena of these stationary tides receives the attention it deserves, and whenever it may appear desirable to study the entire question in a close and thorough manner.

No official reply has been received by the Committee (indeed it was hardly to be expected) in answer to the inquiries made by it respecting an international datum for tidal observations, and as to future concerted action amongst the various maritime Governments respecting a more extended series of tidal observations.

Nevertheless, the advantage of a common international datum, which has for some time been desired, seems to be acknowledged; and though the datum suggested by the Committee has in no way been recognised as such, yet no objections of any moment have been raised against it; while considerable value seems to be attached to it, as having at least done much to advance the desired object, if not to offer the actual solution which is most desirable.

With regard to the second object of the Committee:—to urge the desirability of the Azores Islands as a station, where a series of valuable observations might be carried out upon the tides of the North Atlantic Ocean, it has already been stated that the Portuguese Government readily took up the idea, and had established a self-registering tide-gauge in the Bay of Funchal.

Another incidental duty which fell to the lot of the Committee was to urge upon the Board of Trade the importance of a self-registering tide-gauge at Dover.

That department of the Government, as already reported, set up at its own expense the desired instrument, which is working regularly and giving satisfaction; so that, before long, a series of permanent records may be expected from this most important station, which will serve as data for future observations, when required.

Second Report of the Committee, consisting of Professor P. M. DUNCAN, *F.R.S., and* Mr. G. R. VINE, *appointed for the purpose of reporting on Fossil Polyzoa. Drawn up by* Mr. VINE *(Secretary).*

AFTER many laborious researches, Naturalists, generally, have accepted Dr. Allman's GYMNOLÆMATA, for one at least of the orders of the Class Polyzoa. In this order the 'Polypide is destitute of an epistome (foot) : and the lophophore is circular.'[1] The order is divided into three sub-orders :—

I. *Cheilostomata*, Busk. = *Celleporina*, Ehrenberg.
II. *Cyclostomata*, ,, = *Tubuliporina*, Milne-Ed., Hagenow, Johnston.
III. *Ctenostomata*, ,,

The whole were 'founded by Professor Busk on certain structural peculiarities of the cell.'[2] Only species belonging to two of these sub-orders are found fossil, and to these alone I shall direct attention.

I. CHEILOSTOMATA.—Polyzoa belonging to this sub-order are 'distinguished by the presence of a *movable opercular valve.*'[3] This, however, is not a character on which the Palæontologist can rely for evidence ; but there are others. The ova are usually matured in external 'marsupia,' or ova-cells ; there are also appendicular organs—*avicularia* and *vibricula* ; and later investigations have proved the existence of peculiar perforations in the cell-walls, which Reichert called 'Rosettenplatten,' and Hincks 'communication-pores.' Through these openings the 'endosarcal' cord of Joliet,[4] in the living Polyzoa, passed from cell to cell. The aperture, or mouth of the cell, though variously shaped, is always sub-terminal. To prove that Polyzoa (judging from the calcareous remains) of this sub-order were present in the Palæozoic seas, it is necessary that some one or other of the above-named characters should be present in the species introduced as Cheilostomatous.

II. CYCLOSTOMATA.—The simplicity of structure in this sub-order precludes elaborate description. There are, however, a few points of special structure to which it may be as well to direct attention. The cells are invariably tubular, or nearly so ; the mouths are circular, and, generally speaking, of the same diameter as the cell. The cell-mouths in many of the Cyclostomata are covered by calcareous opercula, in both recent and fossil species, and these are considered to be—by Mr. F. D. Longe[5]—of an analogous character with the *corneous* opercula of the Cheilostomata. Be this as it may—all the Cyclostomatous opercula are calcareous—and their use has not yet been definitely made out.

In his classification of the British Marine Polyzoa, Mr. Hincks bases his genera and species, to a large extent, upon the shape and character of the cell and cell-mouth,—the habit of species is only of secondary importance. To working naturalists amongst living species his carefully worked-out

[1] Hincks' *Brit. Marine Polyzoa*, p. cxxxvi. [2] Ibid. p. cxxiv.
[3] 'Corneous'; Waters on the use of the Opercula. *Proceed. of Manchester Lit. and Phil. Soc.*, 1878. (Italics mine.)
[4] *Nervous Tissue*, Müller.
[5] *Oolitic Polyzoa*, F. D. Longe, F.G.S., *Geo. Mag.*, January, 1881. See also Hincks' *Brit. Marine Polyzoa*, Introduction, p. cv, and pp. 460–1.

divisions are of supreme importance, and the Palæontologist may do well to carry over the leading idea of Smitt and Hincks when working out fossil species, especially so when dealing with Palæozoic types. It may be well, too, to caution the student in his use of the generic names of the earlier authors. These have to be revised according to modern usage. In every case where I could retain the original designation of the author of genera and species I have done so, but it seems to me to be folly to perpetuate a nomenclature which does not indicate generic affinity. In his otherwise carefully written 'Introduction,' Mr. Hincks says, 'There is evidence, however (as I learn on the excellent authority of Mr. R. Etheridge, Jun.), of the existence of a few Cheilostomatous genera at least within this epoch (Palæozoic), and probably the group is represented in the Silurian division of it'[1]—a conclusion, which after the most careful research, I am unable to agree with.

In this, as in my former Report, I shall revise the whole of the genera and species that have been introduced since the time of Goldfuss into the nomenclature of Silurian and Devonian literature. I would prefer to deal only with British species, but as many papers describing new genera and species, from foreign sources, have been published in this country, I cannot do otherwise than review, if not revise, these as well. But whereas, in my former Report I dealt generally with material in my own cabinet, in this I shall refer largely to the Polyzoa in the magnificent collection of the School of Mines, Jermyn Street. For this purpose I have handled, and noted down particulars of every specimen in the collection, from the Lower Silurian to the Devonian. This I have been enabled to do through the kindness of Mr. Etheridge, F.R.S., and Mr. E. T. Newton, Assistant Naturalist of the School of Mines.

Professor Duncan has expressed a wish that in this Report I should draw up a suggestive Terminology, that would be in keeping with modern usage and applicable to Palæozoic species. In accordance with the spirit of this request the following terms may be accepted generally. In it I have followed the leading of Busk and Hincks, without wholly neglecting the terms used by our leading Palæontologists.

ZOARIUM.—'The composite structure formed by repeated gemmation,' =Polyzoarium and Polypidom of authors.

ZOŒCIUM or cell. 'The chamber in which the Polypide is lodged.'

CŒNŒCIUM. 'The common dermal system of a colony.' Applicable alike to the 'Frond,' or 'Polyzoary,' of Fenestella, Polypora, Phyllopora, or Synocladia: or to the associated Zoœcia and their connecting 'interstitial tubuli,' of Ceriopora, Hyphasmapora, and Archæopora, or species allied to these.

FENESTRULES. The square, oblong, or partially rounded openings in the zoarium,—*connected by non-cellular dissepiments*,—of Fenestella, Polypora, and species allied to these.

FENESTRÆ applied to similar openings, whenever connected by the general substance of the zoarium—as in Phyllopora, Clathropora, and the Permian Synocladia.

BRANCHES. The CELL-bearing portions of the zoarium of Glauconome, Fenestella, Polypora, or Synocladia; or the off-shoots from the main-stem of any species.

DISSEPIMENTS. Bars which connect the branches of *Fenestella*, &c.

[1] *Brit. Mar. Poly.*, p. cxviii. Adding in a note 'Of recent genera *Stomatopora* and *Diastopora* appear to occur in the Silurian Rocks.'

GONŒCIUM. 'A modified zoœcium or cell, set apart for the purposes of reproduction.'

GONOCYST. 'An inflation of the surface of the zoarium in which the embryos are developed.' Modern terms from the Rev. Thos. Hincks.

I have no desire to discuss my use of the term 'Polyzoa' instead of 'Bryozoa.' I use it as a matter of choice after carefully considering all that has been said by my friend Mr. Waters, Hincks, Busk and others. After all the question of priority is still an open one, and those of my readers who desire to consult authorities will find ample material in a paper 'On the Priority of the term Polyzoa for the Ascidian polypes' Busk, 'Ann. Nat. Hist.,' 1852, Rev. T. Hincks' 'Brit. Marine Polyzoa,' p. cxxxii, and A. W. Waters' 'Ann. Nat. Hist.,' January, 1880.

Sub-order CHEILOSTOMATA, Busk.

Genus *Hippothoa*, Lamx.

Hippothoa inflata, Nicholson, 'An. Mag. Nat. Hist.,' February, 1871, Pl. xi. fig. 4.

Alecto inflata, Hall, 'Pal.' New York, vol. i. p. 77, pl. xxvi. figs. *7a–7b*.

This species of Hall's has been reworked from fresh material, by Nicholson. The slight figures given by him show a habit nearly akin to *Hippothoa abstersa*, Busk, fig. 6, pl. 22, Busk's 'Crag Polyzoa,' only rather more swollen at the distal part of the cell. In the cell-mouth of Busk's figure the peristome is sinuated: in Nicholson's figure it is circular. There is also a resemblance to Goldfuss' *Aulopora dichotoma*, Tab. 65, Fig. 2. I know of no species of Hippothoa, recent or fossil, with which it can be otherwise favourably compared. Generically it has no affinity with the HIPPOTHOIDÆ of Busk, and without doing violence to the generic character of Hippothoa as given by Hincks,[1] it cannot be placed with the genus. The species, Nicholson says, is abundant in the Cincinnati Group of the Hudson River formation, near Cincinnati, Ohio.

Genus *Retepora*, Imperato.

Ever since this genus was introduced in 1559, it has been used by authors indiscriminately for all manner of fenestrated polyzoa. Lamarck, in 1815, fixed the type of Linnæus, *Millepora cellulosa*, calling it *R. cellulosa*, and since then, the name *Retepora* has been used for a genus of the ESCHARIDÆ. None of the so-called Retepora of the Palæozoic era have any affinity with this family, or even with the genus as now understood. The word should be entirely abandoned for every species of Palæozoic Polyzoa.

1836. *Escharina*, Milne-Edwards.
1847. *Escharopora*, Hall.

As both these genera have been used by authors[2] for Palæozoic species it may be as well to draw attention to its misuse. The types *E. recta* and the var. *nodosa* Hall compares with *Eschara? scalpellum*—now *Ptilodictya scalpellum*, Lonsd., and the Escharina of Milne-Edwards, in

[1] *Brit. Mar. Poly.*, p. 286.

[2] *Escharina angularis*, Lonsd., Morris Catalogue. *Escharipora recta*, Hall, Pal. New York, vol. i.

part, is the Microporella of Hincks, a genus which includes species selected from no fewer than ten genera of recent and fossil Polyzoa.

Laying aside the genus Ptilodictya, I have no knowledge of any other Palæozoic Polyzoa that can be, even provisionally, placed with the Cheilostomata. After careful consideration I am reluctantly obliged to say that at present there is no evidence that the sub-order existed in any of the Palæozoic seas, and further, the evidence is very doubtful until we reach the Mesozoic era. Notwithstanding this decision I shall be amongst the first to acknowledge the earlier existence of types if well-defined evidence is brought to bear in the diagnosis of new discoveries.

Taking into consideration the shape and character of the cell as presenting, apparently, an *Escharidæ* type, I think I cannot do better than begin this Report with a revision of the whole of the *Ptilodictya*. M'Coy [1] places this genus as the fourth in his Family *Escharidæ*; *Berenicea* being the third genus in the family. From the characters given, 'cells shallow, oblong, or ovate, often provided with an operculum, capable of being closed *by special muscles*,' M'Coy evidently believed that the Palæozoic species could be naturally placed in this Family. The true ESCHARIDÆ are of later date, probably not older than the Lower Oolite, and then not as a typical, but only as a kind of passage group. Leaving the classification as an open question at present, I shall take Lonsdale's definition for the group as redescribed by M'Coy:—

1839. *Ptilodictya*, Lonsdale.
1847. *Stictopora*, Hall.

'Zoarium[2] thin, calcareous, foliaceous, or branching dichotomously; branches sometimes coalescing: a thin, laminar, flattened, concentrically wrinkled central axis; set with oblique, short, subtubular, or ovate cells on both sides, with prominent oval mouths, nearly as large as the cells within; branches often flattened, with the margin solid, sharp-edged, striated, and without cells; the boundary ridges of the cells square or rhomboidal.'

This genus is very fairly represented by specimens in the School of Mines. There are no fewer than ten species named, and three marked 'New Sp.' awaiting description. Accepting the work of other authors, I can do no more than furnish notes on them, just as they are named. The first specimen is *P. dichotoma*, Portlock, in the Wyatt-Edgell Col., and is found in the Lower Llandeilo flags, and the species ranges into the Upper Llandeilo and Caradoc. In the Caradoc, also, we have the *P. acuta*, Hall, which, if correctly identified, is very widely distributed in the American and English Silurians of the same horizon; and *P. explanata*, M'Coy. Three species undescribed, but bearing MS. names by Mr. Etheridge: *P. papillata*, *P. ramosa*, *P. scutata*. In the Lower Llandovery we have the *P. fucoides*, M'Coy, a species having a very limited range. In the Upper Llandovery we have *P. lanceolata*, Lonsd., which ranges through the Wenlock Shale, Wenlock Limestone, Lower Ludlow and Aymestry Limestone. There is a departure from the type in *P. scalpellum* (*Eschara? scalpellum*, Lonsd.); it is marked as appearing in the Upper Llandovery and Wenlock Limestone. Hall, in the first vol. of the 'Pal.,' New York, figures and describes *P.* (*Stictopora*) *acuta*, which he compares with this species of Lonsdale. In this species, too, there seems to be no central laminar axis. It is found in the Trenton Limestone. With regard

[1] *Brit. Palæozoic Fos.*

[2] *Corallum*, Lonsdale, M'Coy's *Pal. Fos.*

to *Ptilodictya lanceolata*, Lonsd., and *P. lanceolata*, Goldfuss, there seems to be a little confusion in our varied identifications of species. In the Catalogue of Cambrian and Silurian Fossils,[1] all the *P. lanceolata* found in the Upper Llandovery to the Upper Ludlow series, with the exception of one species found in the Wenlock Limestone, are ascribed to Lonsdale. The Wenlock species is identified as that of *P. lanceolata*, Goldfuss. This confusion is to be regretted, and in justifying the course taken by Mr. E. T. Newton in the Catalogue, I would suggest that the Wenlock shale species receive a new name—*P. Lonsdalia*. There are many characters in this species distinct from the species described by Goldfuss as *Flustra lanceolata*. There is also a pressing necessity that the types of Ptilodictya should become fixed, either as a genus or as a family.

Ptilodictya scalpellum is a type somewhat different from that of other species, and under a family name—PTILODICTIDÆ—I should reconsider my own reference to this genus of the carboniferous *Sulcoretepora*.[2]

Professor Nicholson[3] has added much to our knowledge of this group, by the publication in this country of his papers on American forms. He has also founded two new genera to take in what he considers to be allied types. The Upper Sil. species, which are new, are: 1. *P. falciformis*, Nich.,* allied to *Escharopora recta*, Hall. His species, however, differs from *Flustra* (*Ptilodictya*) *lanceolata*, Goldf. *P. gladiola* and *P. sulcata*, Billings, 2. *P. emacerata*, Nich., a beautifully delicate species, with 'elliptical cells, their long axes corresponding with that of the branches, six or seven in the space of one line measured longitudinally.' 'This Nicholson considers to closely resemble *P. fragilis*, Billings, and it is possible that it may be only a variety of Billings' species.'[4] 3. *P. flagellum*, Nich.: This also resembles *P. gladiola*, Billings, and it also very closely resembles the *P. Lonsdalia* of our own Wenlock shale, excepting that the 'attenuated base' of our own species is rarely 'flexuous,' but more often truncated and round. 4. *P. fenestelliformis*, Nich.: All these species are typical, having the non-poriferous margins and the central laminar axis. One species—*Ptilodictya ? arctiopora*, Nich.—has affinities with *P. raripora*, Hall; but Nicholson doubts the possibility of keeping these two species with the genus. The cells closely resemble some of the characters of our own Silurian species, but as there is evidently a departure from the original types, it may be as well to study these passage forms, if such they be, more carefully than they have yet been done. 5. *P. cosciniformis*,[5] Nich.: Hamilton formation, Bosanquet, Ontario.

For species allied to Ptilodictya, Nicholson has founded two new genera, and adopted one from Hall.

1874.	*Tæniopora*,	Nicholson,	Geological Mag. 1874.
„	*Clathropora*,	Hall,	„ „ „
1875.	*Heterodictya*,	Nicholson	„ „ 1875.

In *Tæniopora* we have a zoarium that is a flattened, linear, calcareous expansion, with cells on both sides, the branches of which are dichotomous. There is a median ridge on each face of the zoarium having a longitudinal direction, on the lateral halves of which the cells are developed. These are longitudinally placed in rows of from three to five. The margins are

[1] *Mus. of Practical Geology*, 1878.
[2] *Carboniferous Polyzoa*, B. A. Rep. 1880, 2nd page of Report.
[3] *An. Mag. Nat. Hist.* March, 1875. [4] Ibid. p. 179.
[5] *Nicholson, Geo. Mag.* Jan. 1875.

*P. falciformis, is Lower [illegible] & Cincinnati.)

usually plain and non-celluliferous. Two species are described: *T. exigua*, Nich., and *T. penniformis*, Nich., both from the Hamilton group.

In *Clathropora* the zoarium is a kind of membranous flattened expansion, with rounded or oval fenestræ of considerable size. The cells are on both sides, separated by a thin laminar axis. The fenestræ are surrounded by a striped non-celluliferous margin. One species is described—*C. intertexta*, Nich.—from the Corniferous Limestone, but in some respects it resembles *P. cosciniformis*, Nich., of which mention has already been made.

In *Heterodicta* the zoarium forms a simple, flattened, unbranched, two-edged frond, with sub-parallel sides. The cells are in two series; the central cells are perpendicular to the base, the lateral cells are oblique. 'In the only species known—*H. gigantea*, Nich.—the cells of a few of the median rows of the frond are straight . . . . and, as I am only acquainted with an exceedingly large species, I should, however, suspect that *Flustra* (*Ptilodictya*) *lanceolata*, Goldf., will very probably turn out to be an example of this genus.'[1]

The material for a thorough revision of this genus is not easily accessible. Many of the Bala series are beautiful casts only, and the Upper Silurian species are often bedded in blocks of the Dudley Limestone; and I think it very unwise to disturb the present nomenclature without sufficient reason.[2] The MS. names of Mr. Robert Etheridge require confirmation, and the best way to do this would be to describe and figure them. The new genera of Professor Nicholson may in the future embrace some few of the forms already described, but we can hardly supersede the clear definitions of Lonsdale's types as given by M'Coy. In the Lower Ludlow rocks specimens of *P. lanceolata*, Goldf., often break up, showing the concentrically wrinkled central axis. In the Girvan District —Scotland—at least two distinct species of this genus may be found—*P. costellata*, M'Coy, and *P. dichotoma*, Portl.

1844. MYRIAPORIDÆ, M'Coy. Family name only.

This is the third family of M'Coy's very restricted classification of Palæozoic Polyzoa. It embraces the Retepora, Lamk. = to Elasmopora, King. The family includes Glauconome, Goldfuss, restricted by Lonsdale, and the genus Fenestella, Lonsdale. It is impossible to retain the family name in the present Report.

1849. *Phyllopora*, King.

There are unquestionably present in both the American and British Palæozoic rocks, species of Polyzoa having some of the inosculating characters of *Retepora cellulosa*. These can neither be referred to Fenestella nor Polypora. My objections to the term Retepora for these have already been expressed. King, also, in his Permian Fossils, has expressed his dislike to this term, and he suggests another word to be used instead—Phyllopora. I prefer this, especially as it has been consecrated by two good workers—Salter and De Koninck. The earliest appearance of the genus, so far as I am acquainted, is in the Lower Llandeilo[3]

[1] *Geological Mag.* 1875.

[2] Since writing the above I have been able to study, very carefully, the leading types of Palæozoic Ptilodictya. In a future paper on the Family PTILODICTIDÆ I shall be able to correct many inaccuracies of our ordinary nomenclature.

[3] School of Mines, iv. $\frac{4}{40}$ in *Catalogue of Camb. and Sil. Fossils.*

flags at Ffairfach. The species is unnamed and it forms one of the specimens of the Wyatt-Edgel collection. The general habit of the specimen is somewhat like Retepora. We have only the reverse of a portion of the zoarium, but in several places the branches are worn and the cells exposed, but not with sufficient distinctness to make out their actual structure. The fenestræ are oval and irregular, and the branches anastomose without dissepiments. A fine large specimen—reverse only —of this type is marked 'Bryozoa,' in case vii. 6/44 of the School of Mines, and as 'Bryozoon' in the 'Catalogue of Cambrian and Silurian Fossils,' p. 105. All the other specimens are very fragmentary, but in the Devonian series there is a matrix of a very fine species. If better fragments could be found in the Devonian rocks, good facilities for the closer study of this type of Palæozoic Polyzoa would be offered.

De Koninck refers two specimens, doubtfully, to this genus[1]—*P.? Haimeana*, De Kon.; and *P.? cribellum*, De Kon. These are amongst the Indian Fossils of Dr. Fleming. In the monograph of Permian Fossils Mr. King refers, and fully describes, *P. Ehrenbergi*, Geinitz, as belonging to this genus. In his paper on the Permian rocks of South Yorkshire,[2] Mr. Kirkby refers fragments of the same species to *Retepora Ehrenbergi* (Phyllopora). The genus is a comparatively rare one, and well-authenticated specimens are also rare. To this genus I refer Nicholson's species[3] —*Phyllopora* (Retepora) *Trentonensis*. It is well described, seeing that his specimens were mere fragments. Salter has already referred to this genus—M'Coy's *Retepora* (Phyllopora) *Hisengeri*—in his catalogue of Silurian Fossils.

1821? *Berenicea*, Lamaroux.

This genus for the present I have allowed to remain with the family *Diastoporidæ*[4]—not as Diastopora, but as provisional. So far as the Palæozoic species are characteristic of the genus we may take M'Coy's description.[5] He says, 'the cells resemble Cellepora, but are not piled,' but with more justness, 'They also resemble the cells of Stictopora (Ptilodictya), but are parasitic and confined to one side. They differ from Discopora by each cell being separated by a small space from its neighbour.' *Berenicea irregularis*, Lonsdale (Silurian Sys.), and *B. heterogyra*, M'Coy, are distinct types. The *Discopora favosa*, Lonsd., Wenlock Limestone, approach nearer to the *Ceramopora* type of Hall and Nicholson.[6]

1828. *Discopora*, Flem.?

Two types of this genus, as understood by Lonsdale, are found in the Wenlock series of Fossils at the School of Mines. One, *D. favosa*, Lonsd., is a beautiful little dome-like species with cells very regularly disposed radiating from the centre. The other is much larger and marked *Discopora favosa?* Lonsd. Both are good types, and they will ultimately find their proper place in our classification. But as Discopora (*Patinella* and *Discoporella* of Busk) it will be at present impossible to retain them, unless under very severe limitation.

1849. FENESTELLIDÆ, King.

After the three very able papers of Mr. G. W. Shrubsole, it will be useless to dwell at much length upon this family. With the whole of Mr.

[1] *Quart. Journ. Geo. Soc.* vol. xix. 1862.
[2] *Journ. of Geo. Soc.* vol. xvii. 1861.
[3] *Geo. Mag.* Jan. 1875, pl. 2, figs. 4–46.
[4] *Quart. Journ. Geo. Soc.* Aug 1880.
[5] Palæozoic Fos.
[6] *Geo. Mag.* 1874–5.

Shrubsole's work I am inclined, generally, to agree. He may be blamed for the limitation of species, but the fault lies not with him, but with authors who have introduced into our scientific literature specific names for fragments that were really portions only of other species. This has already been pointed out, but much yet remains to be done before the family can be considered to be completely revised. It may then be necessary to reintroduce one or two species which are now regarded as synonyms, and also to establish two or three new ones. For the present I can do no other than report on the literature and species which have not yet found a place in the revisions of Mr. Shrubsole.

Gorgonia assimilis, Lonsd., Murch Sil.
Fenestella ,, Cat. Cambrian and Sil. Fos. School of Mines.

This species has been alluded to in Mr. Shrubsole's second paper (p. 247). In the above catalogue it may be found among the Caradoc and Wenlock Limestone series of Polyzoa. This species has not been described, and there seems to be a doubt whether it should be referred to Fenestella or Retepora (Phyllopora).[1]

Many of the earlier specimens—Caradoc and Up. Llandovery—are very indistinct, and complete identification seems to be impossible. The type is a peculiar one, but after going over the specimens I can make out the following characters. The zoarium is irregular and dichotomously branching, no regular dissepiments or fenestræ. The frequent bifurcations of the branches, by infringing upon the lower branches, are the only means by which fenestræ are formed; the number of pores on either side of these vary from ten to thirteen. I cannot therefore suppose that these earlier *Fenestella assimilis* of the Catalogue are in any way related to *Fenestella reteporata*, Shrubsole, of the Wenlock Limestone. So far as I am able to judge from the specimens, they are totally distinct.

The whole of the type specimens of Upper Silurian Fenestella, Mr. Shrubsole has gone over carefully; but as many of these were mere fragments of the reverse, showing no cell-arrangement, he found them altogether valueless for accurate definition. In consequence of this revision the whole of the Upper Sil. FENESTELLIDÆ is put down by him as follows:—

Fenestella rigidula, M'Coy, 'Brit. Pal. Fos.' p. 50, pl. i. C. fig. 19.
,, *reteporata*, Shrubsole, 'Qt. Jour. Geo. Soc.' May, 1880.
,, *lineata* ,, ,, ,, ,, ,,
,, *intermedia* ,, ,, ,, ,, ,,

All these species are found in the Wenlock Limestone, Dudley, and two of them—if not three—in the Niagara Limest., Lockport, America.

Of the Devonian Fenestella but few species are recorded. But as Professor Nicholson has published his papers in this country, we are largely indebted to him for what little is known, besides those that are figured and described by Goldfuss and Phillips.

1826–33. *Retepora* (Fenestella) *prisca*, Gold.[2] Eifel.
,, ,, ,, *antiqua*, ,, ,,
1841. *Fenestella antiqua*; *anthritica*; and *Hemitrypa oculata*, Ph.[3]

[1] 'A Review of the Carb. Fenestellidæ,' *Quart. Journ. of Geo. Soc.* May 1879; 'A Review of the Various Species of Up. Sil. Fenestellidæ, *Quart. Journ. Geo. Soc.* May, 1880; 'Further Notes on Carb. Fenestellidæ,' *ibid.* May, 1881.

[2] *Petrefac. Ger.* tab. 36, fig. 19, tab. 9, fig. 10.

[3] Phillips' *Palæ. Fos. Devon, &c.*

1874. *Fenestella magnifica*, Nichol. 'Geo. Mag.' 1874, pl. ix.
" " *marginalis*, " " " " "
" " *filiformis* " " " " "
" *Retepora* (Fenestella) *Phillipsi* " " "

Many, if not all, of these species are founded upon fragments, or on the reverse only of specimens; and according to the laxness or rigidness with which they are examined, their value in a scientific criticism is of variable importance. They are nevertheless links in the chain of evidence, and until they are displaced by better specimens, which, of course, will allow of better work, they should find a place in this Report. Nicholson, with others, uses the term Retepora very indifferently. Speaking of *R. Phillipsi*, he says, 'This is a genuine *Retepora*, and in its general form and its biserial cells is closely allied to *R. prisca*, Gold., which I have found abundantly in the Corniferous Limestone of Ontario.' As I have already placed Goldfuss's *R. prisca* with the FENESTELLIDÆ, I cannot do otherwise with this one.

In addition to this species Nicholson founded two new genera for Devonian Fenestella:—

1874. *Cryptopora*, 'An. Mag. Nat. Hist.' Feb. 1874.
" *Carinopora* " " " " "

Two species—*Cryptopora mirabilis*, Nich., and *Carinopora Hindei*—Nicholson places to these new genera. With all due respect for Professor Nicholson and his work, I must take his admission that these are apparently *Fenestellidæ*, and as such there was, I am inclined to think, no need for founding new genera for their reception. The author refers to *Hemitrypa*, and, in one sense, compares his genera with the genus of M'Coy. Unfortunately for the fate of all three genera, we have only true Fenestella encrusted by a coral, and the diagnosis of the species given by both authors is encumbered with partly coraline and partly polyzoal structures. All the illustrations which Professor Nicholson gives are structures found in typical Fenestella,[1] with the exception of Fig. 2 *g*, p. 81. Here the 'carina,' or keels, are apparently united by 'stolons,' which may be sections of the tabulæ only of the encrusting coral. Fig. *f* is without this 'stoloniferous' connection, but both are sections of branches cut through perpendicular to the surface, and showing the largely developed keel, with the transverse section of the cells. Fig. *i* is one of these, isolated. It would be better to view the structures reversed. Figs. *d* and *e* are evidently ordinary Fenestella, and the sections above described are portions of the same frond.[2] The development of the keel is remarkable, and speaking of *C. Hindei* Nicholson says, 'The thickness of the frond, measured at right angles to its plane of growth, is one line or a little more, nearly two-thirds of this being accounted for by the great internal keels.' This is equalled by the species *F. Lyelli*, Dawson, which is figured and partly described in 'Acadian Geology.'[3]

1826–33. *Glauconome disticha*, Goldf. Petr. Germ.
1874–5. *Ramipora*, Toula, Permo-Carbon. Fossilien.[4]
? 1878. " *Hochstetteri*, Toula, Bigsby, Devonian Carboniferous.
1879. " " var. *Carinata*, R. Eth. Jun. 'Geo. Mag.' 1879.

[1] See the illustration in the *An. Mag. of N. Hist.* Feb. 1874.
[2] I wish the reader to refer to Nicholson's paper as given above.
[3] *Carb. Limestone*, pp. 288–9.
[4] See *Arctic Pal. Polyzoa*, R. Etheridge, Jun., 1878. Jour. Geo. Society.

I arrange these genera and species, not because they are allies, but because they are the reverse of that. The genera are as distinct as genera can be, yet they have been confounded by authors. The *G. disticha* of Goldfuss is, I think, distinctly an Upper Silurian type. The Bala type of *Glauconome* is a different genus; and *Ramipora*, as described by Toula, has five or six rows of irregular pores. The genus *Ramipora* is a Permo-Carboniferous type, and although having some facial resemblance to the species from the Bala beds, and figured as *Ramipora*, var. *carinata*, Eth. Jun.[1], by Mr. Robert Etheridge, Jun., the two forms differ in many respects considerably. *Ramipora* is much larger naturally than the Bala *Glauconome*; the cells are differently arranged. In the Lower Silurian species, both the primary and the secondary branches bear two rows of alternately arranged cells. Having handled and carefully examined the specimen in the School of Mines, figured by Mr. R. Etheridge, jun., *Ramipora Hochstetteri*, var. *carinata*, Eth., I can bear willing testimony to the faithful delineation of this beautiful type.

There are several specimens of this as yet undescribed genus in the collection already named, and their study will afford a good general idea of the varying habit of the species.

1844. *Polypora*, M'Coy.

Zoarium a delicate, reticulated, calcareous expansion. Branches round, from three to five rows of cell-openings—margins usually not projecting, branches connected (occasionally) by thin dissepiments.

This genus is represented by only one species, *P. crassa*, Lons., in the Wenlock Limestone, Dudley. The genus was more fully represented in America in the Devonian strata,—in our own country—in the Arctic regions—and India during the Carboniferous epoch. Professor Nicholson[2] describes and figures three species: *P. pulchella*, Nich., *P. tenella*, Nich., *P. tuberculata*, Nich. As a *P. tuberculata* has been previously described by Prout[3] the name of Nicholson is rather unfortunate, as there is a difference in the two species, for Nicholson says his is allied to *P. verucosa*, M'Coy, and as such it differs from Prout's *P. tuberculata*, if the identifications of the Messrs. Young be correct. *P. pulchella* and *P. tenella* are nearly allied to *P. Halliana*, Prout, which occurs 'in the St. Louis Group of Illinois, and which I have likewise detected in the Corniferous formation of Ontario.'—Nicholson.

I have now gone over all the genera wherein the cell-characters are either ovate or sub-tubular, without saying arbitrarily that these genera and species belong to the CYCLOSTOMATA. I have begun with the species having the nearest apparent affinities with the CHEILOSTOMATA, and then allowed the others to fall in, in a consecutive order. This temporary arrangement will be better for the present, and this will allow time for a proper classification when the whole of the Palæozoic Polyzoa have been more closely studied. The following genera I have not the least hesitation in placing with the Cyclostomata as at present understood.

1859. CYCLOSTOMATA, Busk.

'Cell tubular; orifice terminal, of same diameter as the cell, without any moveable apparatus for its closure; consistence calcareous.'[4]

[1] *Geo. Mag.* 1879.
[2] New Devonian Fossils, *Geo. Mag.*, 1874.
[3] Trans. of Acad. of Science, St. Louis, *Geo. Mag.*, June, 1874.
[4] Monograph of the Crag Polyzoa, p. 9.

1825. *Stomatopora*, Bronn.

1821. *Alecto*, Lamx. 1826. *Aulopora* (pars.) Goldfuss.

'Zoarium closely adnate throughout, simple or irregularly branched; branches linear or ligulate; cells disposed in a simple series or in more or less regular transverse rows of from two to four.'[1]

A few types of this genus are present in the Palæozoic rocks of this country—in the Devonian of Eifel—and in America.

James Hall, in his 'Pal.' of New York, vol. i., records the existence of *Alecto inflata* in the Trenton Limestone. This is a very simple serial species of a most remarkable type. From the same stratum he records another species, *Aulopora arachnoidea*, altogether different from the first type. Except that Hall calls these species 'corals,' there are not in his descriptions any characters that would prevent them being properly placed with the Polyzoa. I have already alluded to this species, *A. inflata*, Hall, when writing of *Hippothoa*. I now restore it to its proper place.

1874. *Alecto auloporides*, Nich.[2]
„ *frondosa* = *Aulopora frondosa*, James.
1874. „ *confusa*, Nich.

These seem to be true Stomatopora (Alecto of Busk), and their existence is recorded by Nicholson as appearing in the Lower Silurian or Hudson River Group. One species, *A. auloporides*, as a branching form, survives into the Niagara Limestone. In the Caradoc series of Fossils in the School of Mines, a small specimen of Polyzoa is marked *Heteropora*, allied to *H. crassa*.[3] This is a very peculiar species, but in no way related to Heteropora as now understood. The cells are short and tubular, alternately placed on the sides of the branch, very similar to the figure given by Nicholson. Having carefully examined the specimen, I therefore—temporarily—place it as a variety, at least, of *Stomatopora auloporides*, Nich.

I have, since the above was written, discovered no less than three distinct species of *Stomatopora* in the Upper Silurian Shales of Shropshire. One I have figured and described—*S. dissimilis*, Vine.[4] Of the others I have not yet sufficient details to allow of description. I have also discovered two species of *Ascodictyon*,[5] full details of which will be published. In King's Monograph of Permian Fossils, pl. 3, fig. 13, a figure is given of —apparently—a badly preserved specimen of Stomatopora. It very much resembles the species of Hall, but no cell-mouths are given. King names it *Aulopora* (*Stomatopora*) *Voigtiana*, King.

1839. *Diastopora* (*Aulopora*) *consimilis*, Lonsd.

A species of Polyzoa, named as above, is in the Ketley Collection at the School of Mines. It is found in the Wenlock Limestone series, but no locality is given. This is the *Aulopora consimilis* Lonsd. of the Silurian System, pl. 15, fig. 7. I have found fragments in the washings of Mr. Maw.[6] Another specimen of the same species, from the Wenlock Limestone, Dudley, encrusting a small coral, is in the cabinet of

[1] Busk, *Cyclostomata*, p. 22.

[2] Paper read at Brit. Assoc., Belfast; printed, *An. Mag. Nat. Hist.*, 1875.

[3] *Catalogue of Silurian Fos.*, p. 44, case vii. $\frac{4}{67}$.

[4] Geo. Soc. Pap. read June 22, 1881.

[5] Nicholson, *An. Mag. Nat. Hist.*, June, 1877.

[6] In plate 15, *Silurian System*, reproduced as pl. xli., *Siluria*, ed. 1859, marked 7, *Diastopora ? consimilis*, probably a Bryozoon.

Mr. Longe, of Cheltenham. In the Devonian collection of Polyzoa, at the School of Mines, a species marked *Berenicea M'Coyii*, Salter, Middle Devonian, Padstow, bears a very close resemblance to this Silurian type. Unfortunately the Devonian specimen is very poorly preserved, but I can trace in the zoarium a sufficient number of cells to afford me some idea of the general character. The specimen in Mr. Longe's cabinet I have carefully studied, and I now give a description with very accurate measurements.

Zoaria encrusting by a single layer a fragment of coral. *Zoœcia* tubular, rather regular, in series. As several colonies are found upon the same coral, a remarkably irregular character is given to the associated *zoaria*. For the purpose of this diagnosis I isolate a single colony. Cell-mouths circular, with a well-formed peristome, and slightly less than the diameter of the tubes. Six *zoœcia* occupy the space of a line measured across the mouths of the cells, and two and half, to three, lengthwise in the same space.[1]

The habit of Lonsdale's species in the School of Mines, and also Salter's Devonian Berenicea, is that of the ordinary Diastopora. The habit of the species here described, and also the measurements, correspond with Nicholson's *Alecto confusa*. If these be true Diastopora—for I cannot ignore the existence of *D. consimilis* and *Berenicea M'Coyii*—we have a true tubular Diastopora carried backward in time to the Wenlock Limestone; consequently the Berenicea which I left provisionally with the *Diastoporidæ*,[2] will be displaced by undoubted tubular species. The measurement of *Alecto confusa*, Nich., is five cells to the line, measured across the mouth.[3] This is slightly less than my own, and may be accounted for by the more compact arrangement of the cells in the Dudley specimen.

1826. *Ceriopora*, Goldfuss.

Several species of this genus are given as Upper Silurian by authors,

Ceriopora affinis, Goldfuss.
,, *granulosa*, ,,
,, *punctata*, ,,

and Nicholson in his New Devonian Fossils adds *Ceriopora ? Hamiltonensis*, of which he says, 'This beautiful little fossil (about five cells occupy the space of a line vertically) occurs in great abundance in some of the beds of the Hamilton Formation. It is allied to *C. punctata*, Gold., and *Millepora interporosa*, Phill. ('Geo. of York.') I am at present unable to decide as to its true generic affinities, and have simply referred it provisionally to Ceriopora.' I will also leave it and the other species alone for the present. The whole of the *Cerioporidæ* will have to be revised, and species from the Silurian to the Crag will have to be re-worked.

1821. *Spiropora*, Lamx.

In some of the shale-washings supplied to me by Mr. Maw from strata below the Wenlock Limestone, I have come across many beautiful frag-

[1] This was written in December, 1880, a copy of which was furnished shortly after to Mr. Longe, for his correction and approval for publication in this Report, as *Alecto confusa*, Nicholson? var. *regularis*. I have seen since that a paper has been read by him on *Diastopora*, at the Geological Society, May, 1881. I have no desire to press my own name in preference to his, seeing that I wrote my description previously to the examination of Lonsdale's and M'Coy's Silurian and Devonian species in the School of Mines.

[2] Review of the Fam. Diastoporidæ, *Quart. Jour. Geo. Soc.*, Aug. 1880.

[3] Nicholson does not say this, but I infer it from his remarks.

ments of this genus, which will enable me to carry back the type to Silurian times. Mr. R. Tate has already carried back the genus to the Lias,[1] but the specific differences between the Liassic and Silurian forms are very marked. The Silurian species I shall describe under the name of *Spiropora regularis*, Vine.

1874. *Botryllopora*, Nicholson.[2]

This curious genus, founded by Nicholson for Devonian species, is allied to Defrancia and Lichenopora, but unlike either. The author says 'I have been unable to refer these singular Polyzoa to any existing group, and have therefore been compelled to found a new genus for their reception. Zoarium calcareous, sessile, and encrusting, forming systems of small circular discs, the upper surfaces of which are marked with radiating ridges, upon which the cells are carried. Each disc is attached by its entire lower surface, slightly convex above, with a central nonporiferous space, round which a number of radiating poriferous ridges occupy an exterior, slightly elevated zone. Cells forming a double series on each ridge, immersed with rounded mouths, which are not elevated in any part of their circumference above the general surface.'[3]

One species is given, *B. socialis*, Nich. Pl. ix. fig. 16, and it is not of very rare occurrence in the Hamilton Formation. I have not seen among any of our own Palæozoic Polyzoa any approach to this genus. It may be well to direct attention to the characters, because workers may find even this amongst the group of our hitherto most neglected fossils.

In my first Report ('British Carboniferous Polyzoa,' 1880[4]) I said that "to the Palæontologist the study of the Palæozoic Polyzoa opens up many very important biological details; for the connection of the Polyzoa with the Graptolites is a question that must be dealt with in detail."

Since this was written I have gone over much that has been written in this country on this debatable subject. Professor Huxley, Mr. Salter, and Professor H. Alleyne Nicholson have severally occupied themselves with this question of affinity. Mr. Salter says, 'I think Professor Huxley first suggested the resemblance to *Defrancia*'[5]; his own opinion, however, was very decidedly expressed. 'The point I would chiefly call attention to is that there is a complete series up to the most compound in this remarkable family'; and after pointing out the varied features of the leading types of the *Graptolitidæ*, he concludes by saying '*Dendrograptus* has the branches numerous, unsymmetrical, and crowded, while *Dictyonema* completes the series by showing the numerous rod-like stems each with their cells in double rows, connected by numerous transverse bars into a network like that of *Fenestella*, to which, indeed, I believe it forms the passage group.'[6] Professor Nicholson, after examining in detail the various points raised by Mr. Salter, says, 'The "polyzoarium" (of the Polyzoa) is commonly more or less highly charged with lime, and this is especially the case with the fossil-forms. The polypary of the Graptolites, on the other hand, are invariably corneous (or chitinous).'[7] Notwithstanding these varied opinions, I very reluctantly reviewed the whole of the points mooted by Nicholson and others, and then submitted my notes to

[1] *Spiropora liassica*, Tate, *Geo. Mag.*, 1875.
[2] *Canadian Jour.*, No. 80, *Geo. Mag.*, 1874, p. 23. [3] Ibid. p. 23.
[4] *British Association Reports.*
[5] *Memoirs of the Geological Survey—North Wales*, p. 328, 1866.
[6] Ibid. [7] *British Graptolitidæ*, p. 85.

Vertical Range of Silurian Polyzoa or Species described.

Museum of Practical Geology, Siluria and Silurian System.

Genus	Species	Author	Formation	Catalogue page	My own Collection marked *
Phyllopora	sp.		Lower Llandeilo	20	
Ptilodictya	*dichotoma*	Portlock	” ”	”	
”	”	”	Upper ”	28	
Fenestella	sp.		” ”	”	
Diastopora?	*heterogyra*	M'Coy, *Berenicea*	Caradoc	44	*
Fenestella	*assimilis*	Lonsdale	”	”	
”	*Milleri*	”	”	”	*
”	*regularis* and sp.	Portlock	”	”	
Glauconome	*disticha* (?)	Goldfuss	”	”	*
Heteropora?	*Alecto confusa* type	Nicholson	”	”	
Phyllopora	*Hisingeri*	M'Coy	”	”	*
”	*ornata*	M. S. Wyatt-Edg.	”	”	
Ptilodictya	*acuta*	Hall	”	45	
”	*dichotoma*	Portlock	”	”	*
”	*explanata*	M'Coy	”	”	*
”	*papillata*	M. & Etheridge	”	”	
”	*ramosa*	”	”	”	
”	*recta?*	Hall	”	”	
”	*scutata*	M. & Etheridge	”	”	
Retepora?	*ramosa*	Hisinger	”	”	
Fenestella	sp.		Lower Llandovery	64	
Glauconome	*innexa.*	Salter	” ”	”	
Phyllopora	sp.		” ”	”	
Ptilodictya	*fucoides*	M'Coy, cast of cells only	” ”	”	
Fenestella	*sub-antiqua*	D. Orb	Upper ”	72	
Ptilodictya	*lanceolata* (*Lonsdalia*, Vine)	Lonsdale	” ”	”	*

Fenestella	sp.	. . . .	Wenlock shales	95	*Stomatopora dissimilis* Vinc.
Ptilodictya	*lanceolata*	,,	From these shales I have obtained several specimens of species in the right-hand side. Species also of *Ptilodictya Lonsdalia*, *P. scalpellum*, *Polypora*, *Glauconome*, and *Ceriopora*, &c.		,, sp. *Ascodictyon*, 2 sp. *Spiropora*, sp.
Ceriopora	*oculata*	Goldfuss	Wenlock Limestone	104	*
Diastopora	*consimilis*	Lonsdale	,, ,,	,,	* From Wenlock Shale.
Discopora	*favosa*	,,	,, ,,	,,	*
Fenestella	*assimilis?*	,,	,, ,,	,,	*F. intermedia*, Shrub.*
,,	*Lonsdalei?*	D. Orb	,, ,,	,,	*F. reteporata*, Shrub.*
,,	*Milleri?*	Lonsdale	,, ,,	,,	*F. lineata*, Shrub.*
,,	*reticulata?*	,,	,, ,,	,,	
,,	*rigidula*	M'Coy	,, ,,	,,	
,,	*sub-antiqua*	D. Orb	,, ,,	,,	
Glauconome	*disticha*	Goldfuss	,, ,,	105	*
Polypora	*crassa*	Lonsdale	,, ,,	,,	*
Ptilodictya	*lanceolata*	Goldfuss	,, ,,	,,	*
,,	*scalpellum*	Lonsdale	. . . .		
Phyllopora	marked *Bryozoon*	Reverse only	,, ,,	,,	*Berenicea irregularis*, Lonsdale.*
Ceriopora	*oculata*	Goldfuss	Lower Ludlow	119	I have several unworked species of Polyzoa from the Wenlock Lim. series.
Diastopora	*Berenicea* sp.	. . . .	,, ,,	,,	
Ptilodictya	*lanceolata*	Lonsdale	,, ,,	,,	
	This is more of the type	*P. lanceolata*, Goldfuss			
,,	*lanceolata*	Lonsdale	Aymestry Limestone	125	
Ceriopora	*granulosa*	Goldfuss	Upper Ludlow	131	
Discopora	sp.	. . . .	,, ,,	,,	
Ptilodictya	n. sp.	. . . .	,, ,,	,,	

Mr. Lapworth's scrutiny before publication. He has gone over every one of these notes critically, and, as his decision is adverse to my own views (founded to a large extent upon facial resemblances), I cannot do otherwise than bow to his dictum. 'If the Polyzoa and the Graptolithina had a common ancestor—a view I have always been disposed to adopt myself—it must have existed at an antiquity far more greatly removed from Silurian times than Silurian time is from our own ages; for the differences which then separated the two groups appear to have been almost as gigantic in importance as those which divide the Hydrozoa and Polyzoa of the present day.[1]

For the purpose of comparison I append a list of the leading genera of the Graptolites with the genera of Polyzoa found in the same formations.

Vertical Range of GRAPTOLITES, according to Nicholson, Lapworth, and Catalogue of Cambrian and Silurian Fossils, School of Mines.

(L.) Lapworth. (N.) Nicholson. (S.M.C.) School of Mines Catalogue.

Formation.	Genera only given, with corresponding increase of Polyzoa.
Cambrian.	*Oldhamia antiqua*, Forbes; *O. radiata*, Forbes (S.M.C. p. 8).
Up. Lingula Flags.	*Dictyonema sociale*, Salter (S.M. p. 12), also in Tremadoc slates (N.)
Arenig and Llandeilo.	Dichograptus, Didymograptus, Tetragraptus, Climacograptus, Diplograptus, Graptolithus, Rastrites, Dictyonema? Phyllograptus, Graptolithus (S.M.C. pp. 17–18), Trigonograptus, Ptilograptus, Dendograptus, Callograptus, Dictyograptus (Lap.) POLYZOA: Phyllopora, Ptilodictya (Lower Llandeilo), Branching polyzoon (S.M.C. p. 20), hardly distinguishable in form from Graptolithina, only it is calcareous.
Up. Llandeilo.	Didymograptus, Tetragraptus, Climacograptus, Diplograptus, Dicranograptus, Graptolithus, Rastrites, Dictyonema, Protovirgularia, Helicograptus, Pleurograptus, Dicellograptus, Cyrtograptus (S.M.C. pp. 23–24). POLYZOA: Ptilodictya and Fenestella? n.p. (Ibid. p. 28).
Caradoc.	Climacograptus, Diplograptus, Dicranograptus, Dendograptus, Graptolithus (S.M.C. p. 31). POLYZOA: Berenicea, Fenestella, Glauconome, Phylopora, Ptilodictya, great increase of species (Ibid. p. 44).
Lower Llandovery	No Graptolites in S. M. C., Climacograpsus one sp., *Graptolites priodon*, Bronn (Nich. Mono. pp. 97, 98). POLYZOA: Fenestella? Glauconome innexa, Phyllopora, Ptilodictya.
Up. Llandovery	*Graptolithus priodon*, Dictyonema (S.M.C. p. 69). POLYZOA: Ptilodictya, Fenestella.
Wenlock Shale	Cladograptus, Cyrtograptus, Graptolithus, Retiolites, Dictyonema (S.M.C. p. 81). POLYZOA: Fenestella, Ptilodictya (Stomatopora species. Vine).
Wenlock Limestone	*Graptolithus priodon*, Bronn (S.M.C. p. 93), *Graptolites colonos*, Retiolites, Cyrtograpsus, Ptilograpsus (Nich. p. 98). POLYZOA: great increase of species, *see* list.
Lower Ludlow	Dendograptus, Graptolithus (S.M.C. p. 115). Four species recorded both in Catalogue and the same by Nicholson.
Upper „	Graptolithus sp. recorded (S. M. Cat. p. 128).

[1] Concluding remark in Mr. Lapworth's letter to me, May 16, 1881.

Report of the Committee, consisting of Dr. M. FOSTER, *the late* Professor ROLLESTON, Mr. PYE-SMITH, Professor HUXLEY, Dr. CARPENTER, Dr. GWYN JEFFREYS, Mr. F. M. BALFOUR, Sir C. WYVILLE THOMSON, Professor RAY LANKESTER, Professor ALLMAN, *and* Mr. PERCY SLADEN (*Secretary*), *appointed for the purpose of aiding in the maintenance of the Scottish Zoological Station.*

THE Committee beg to report that with the aid of the grant (50*l.*) voted last year, they have been able to assist in the maintenance of the Station whilst at Cromarty. The most important work undertaken during this period has been the 'Observations on the Locomotor System of the Echinodermata,' by Mr. Romanes and Professor Ewart. The paper containing the results of the investigations, having been constituted the Croonian Lecture, was read at the meeting of the Royal Society, held on March 24. A short account of the work was given in 'Nature,' No. 597, vol. 23; and an abstract will appear in the 'Proceedings of the Royal Society.'

The authors report that during their investigations they directed attention chiefly to the structure and function of the ambulacral and nervous systems. By injection, they satisfied themselves:—

(1) That the ambulacral was independent of the blood-vascular system, and that both systems were in communication with the external medium at their common origin in the madreporic plate—the blood-vascular system being in freer communication with the exterior than the ambulacral system.

(2) That in the common Holothurian, the ambulacral fluid passed from the circular canal into five small sinuses, from which it might either enter the radial canals or the large sinuses at the bases of the tentacles.

Of the nervous system, it was shown that in Echinus the lateral branches from the radial trunks escaped with the pedicels and blended with an external sub-epidermic plexus, which extended on to the spines and pedicellariæ.

In the physiological part of the paper it was pointed out—

(1) That the natural movements of the echini exhibit great co-ordination, and further, that Echinoderms when inverted always right themselves.

(2) That Echinoderms endeavour to escape from injury in a direct line from the source of irritation.

(3) That the pedicels, spines, and pedicellariæ approximated when any part of the surface of the shell was irritated.

(4) That severe internal or external irritation had a powerful influence on the spines and pedicels.

(5) That starfish and echini, when their eye-spots are intact, crawl towards the light.

(6) That detached rays of starfish act in the same way as the entire animal, while division of the radial nerves destroys co-ordination among the rays.

(7) That if echini be divided into several portions, the pedicels, spines, and pedicellariæ of these portions continue to exhibit local reflex irritability; and if a portion contains an entire row of pedicels, it is able to crawl about and, when inverted, to right itself.

(8) That the pentagonal nerve-ring, through having no influence on the pedicellariæ or on the local reflex action of the spines, has a more centralizing function than any other part of the nervous system.

The work of the Station is being continued this autumn at Oban. The Committee again respectfully solicit assistance and urge the renewal of the grant.

During the autumn of 1880, a total sum of 120*l.* was spent in connection with the Zoological Station while at Cromarty. The 50*l.* voted by the British Association was partly used for providing apparatus and reagents, and partly for paying for the use of a steam-launch and for boatmen.

Report of the Committee, consisting of Dr. M. FOSTER, Professor ROLLESTON, Mr. DEW-SMITH, Professor HUXLEY, Dr. CARPENTER, Dr. GWYN JEFFREYS, Mr. SCLATER, Mr. F. M. BALFOUR, Sir C. WYVILLE THOMSON, Professor RAY LANKESTER, Professor ALLMAN, *and* Mr. PERCY SLADEN (*Secretary*), *appointed for the purpose of arranging for the occupation of a Table at the Zoological Station at Naples.*

YOUR Committee have the pleasure of reporting the continued success and prosperity of the Zoological Station at Naples. During the past twelve months a greater number of naturalists have availed themselves of the facilities there afforded for investigation than in any previous year. This of itself is an encouraging testimony to the excellent management of the establishment, and also forms an index of the continued and increasing support accorded to the Station by all the chief European nations. It may be said truly, and without exaggeration, that no institution could be more cosmopolitan in its principles of organisation, or fulfil more admirably the purpose of its existence. The biologists of all civilised countries are under a debt of gratitude to Professor Dohrn for the energy and self-sacrifice he has bestowed on this noble undertaking.

Each annual report issued from the Station contains an account of some general improvement made in the laboratories, or of the addition of new appliances or apparatus likely to be of service to the working naturalist; in fact, every opportunity is taken by the Directorate to provide whatever the developments of modern methods of investigation render indispensable, or even desirable, for the success of a student.

(Laboratory).—It is scarcely necessary for this Committee to specify in detail the various items added to this department during the past year, and of which a full account is to be found in the last 'Bericht über die Zoologische Station' by Dr. Dohrn, published in the 'Mittheilungen aus der Zool. Station,' Bd. ii., Heft 4. It will suffice to mention that the recent additions to the laboratory comprise micro-spectroscopic and polariscopic apparatus, a new Du Bois-Reymond section apparatus, and also a valuable series of chemico-physiological apparatus; the latter through the munificence of the Berlin Academy, by whom an excellent microscope (of Hartnack's make) has likewise been presented. This instrument will naturally be placed in the first instance at the disposal of the occupant of the Academy table.

The general arrangements for the circulation and distribution of sea-water throughout the establishment have been considerably improved. In all the small separate work-rooms, tanks similar to those in the large laboratory have been erected, and the number of small portable breeding aquaria has also been increased. The aërating apparatus, which have now been in use for some time, having proved so satisfactory for developmental investigations, a larger apparatus of the same description is about to be constructed, in order to supply a current of air of greater strength and capable of subdivision.

(*Library*).—The library is being continually increased by the exchange of publications with other institutions and by donations from authors, whilst a number of the older systematic works and descriptions of travels have recently been purchased. A new appendix to the library catalogue is issued in the 'Mittheilungen,' Bd. ii., Heft 4.

(*Publications*).—The various publications undertaken by the Station, and brought out under its auspices, are now well before the scientific public, and have already received a worthy and well-merited meed of praise.

(1) Of the series entitled 'Fauna und Flora des Golfes von Neapel' two monographs have been issued since the last report, viz., 'Die Ctenophoren des Golfes von Neapel' by Dr. Carl Chun, and 'Le Specie del Genere Fierasfer nel Golfo di Napoli' by Dr. Carlo Emery. Three monographs are announced to appear during the present year, viz. :—

Monographie der Pantopoda (Pycnogonidæ), by Prof. Anton Dohrn.

Die Corallineen, by Graf zu Solms-Laubach.

Monographie der Gattung Balanoglossus, by Dr. J. W. Spengel.

Of these the two first-mentioned are now in the press, and the plates of Dr. Andres' monograph on the Actiniæ, which will be published subsequently, are already in the lithographer's hands. A list of twenty-two monographs has been promised for this series up to the present date.

(2) Of the 'Mittheilungen aus der Zoologischen Station zu Neapel,' vol. ii. is now completed, and vol. iii., part i., is in the press. Many valuable memoirs have already been published in this periodical.

(3) The 'Zoologischer Jahresbericht' for 1879 was issued at the end of last year, and that for 1880 is already in the press. The 'Bericht' for 1879 occupied 1,250 pp. and formed two thick volumes, comprising the labours of thirty-six referees. The present Report will not be less bulky, but will be issued—with a view to the convenience of many naturalists—in four parts. These will be independently paged, and may be purchased separately. The division of the work will be as follows :—Part 1. Lower Animals; 2. Arthropoda; 3. Mollusca; 4. Vertebrata.

(*Submarine Collecting*).—During the past two years very important service has been rendered to the Station by the introduction of diving, not only as a means of collecting, but also of investigating *in situ* the fauna and flora of shallow and moderate depths. As the application of this method to Natural History purposes is novel, the following particulars may not be without interest.

Nearly three years ago, Dr. Dohrn conceived the idea that some of the modern appliances for diving might be made use of for the purposes of the Zoological Station; and being at that time in Berlin, a journey was forthwith taken to Kiel, for the purpose of making preliminary experiments. The water was not especially clear where the descent was made, in consequence of the bottom being somewhat muddy; nevertheless, shells and other objects were to be seen distinctly, and the conviction was established that in the clear water of the Mediterranean, advantageous results would be obtained by the employment of diving. On returning to Italy Dr. Dohrn made application to the Italian Minister of Marine for the loan of a 'Scaphander' apparatus, a request which was granted with the greatest liberality. By means of these appliances Dr. Dohrn and several of the gentlemen of his staff have been enabled during the last two years to investigate, by actual inspection, the coast and sea-bed at the following localities:—The neighbourhood surrounding the Castel dell' Uovo, the sea-bed of the Chiaja and Mergellina, all the coast and grottos of Posilippo, the Secca della Gajola, the whole of the circumference of Nisita, the bay of Baja between Pozzuoli and Capo Miseno, the coasts of Procida and Vivara, the Secca di Vivara, different points of the coast of Ischia, also a few at Ventotene and Ponza, as well as some places round Capri, the Blue Grotto, the Siren Islands, and some grottos at Amalfi. These explorations are continued as often as the weather permits.

Practice and experience have enabled several improvements to be effected; and, indeed, much more depends upon the successful management of the diving apparatus than upon the possession of the apparatus itself.

It is of primary importance that the diver should be a strong man, able to carry, when out of water, his 165 lbs.—the weight of the dress and its appurtenances. This is a factor upon which so much rests that it needs especial notice. In water, however, the apparatus becomes naturally lighter to carry the deeper the diver proceeds, and even in four or five fathoms he is able to move about quite conveniently with it. For the satisfactory attainment by diving of the objects of a zoologist or botanist, free movement on the sea-floor is unquestionably a *sine quâ non.*

The mere fact of descending or of being let down is comparatively unproductive if the diver is not able to seek out special localities where animal and plant life is richest and most varied; and he would even be led to conclude that uniformity of character exists on the sea-floor. In order that the diver may move about freely and without impediment, the boat which carries the air-pump must always follow his course,—this being shown by the bubbles of air which ascend from the helmet and are continually bursting on the surface of the water. The diving-boat should be large and strong, and will require the following complement. Two men for rowing, two for keeping the pump continually in motion, and, as this is fatiguing work, it will be desirable to carry an extra man as relief, especially if more than one person is diving; whilst another man, making five or six in all, is needed to attend to the diver's signal rope, for the purpose of communication,—the signs being given by pulling or jerking at this rope. For further convenience, it is desirable to have a small jolly-boat near by, carrying tubs and buckets for the reception of the stones, rock-fragments, or other booty which the diver sends up in the net or fish-basket which is let down to him repeatedly. The diver himself is armed with hammer and chisel, and will be able, if only cautious that none of the glasses in his helmet are broken accidentally, to remain an hour or two at the bottom of the sea, according as he may wish or as his powers last. Currents are his greatest enemy, and these are sometimes so strong as to knock the diver down, or if within reach of the action of the waves he may be pitched about hither and thither with such force that a strong man becomes fatigued in half an hour and has to be drawn up again. In a tidal sea these forces must be regarded as great hindrances to the convenient use of diving apparatus.

It is scarcely necessary to indicate the special advantages which are likely to accrue from the use of diving as an agent in Natural History research;—they are of themselves self-evident. By this means it is possible to explore fissures, cavities, or the under-side of overhanging rocks, and similar parts of the sea-bottom which are naturally inaccessible either to the trawl or the dredge. The examination of all such places is of the greatest importance for the collection of Sponges, Hydroids, Actiniæ, Bryozoa, and all sessile organisms; as well as for Planarians, Nudibranchs, and other Mollusca; and for the Algæ, perhaps, chief of all. Furthermore, by the aid of a diving apparatus important material, of the description just enumerated, may be readily procured in large quantities, whilst the association and variations of organisms may be studied with the greatest accuracy. Notes can be written, or even sketches made, by the diver without difficulty; and direct observations obtained on the conditions of environment. A more definite knowledge of the distribution of a marine Fauna and Flora is thus rendered possible than by any other means of investigation; and we have here a method of approaching many problems which had hitherto seemed inaccessible, and whose solution has been wholly hypothetical.

Amongst the rarities recently procured may be mentioned:—*Rhodosoma* (*Chevreulius*) *callense*, Heller, the northern *Lophogaster typicus*, Sars, several new forms of parasitic *Bopyridæ*, as well as various *Scopelidæ.*

(*The Preservation of Specimens*).—This has always been an important feature in the general routine of the Station. Experience and careful investigation have brought about numerous improvements in the methods of treating different groups of organisms; and success has been attained in various cases which had hitherto been regarded as impracticable. In testimony of the excellence of manipulation, it may be mentioned that at the International Fishery Exhibition, held at Berlin, in 1880, a First Prize and Gold Medal were awarded to the Zoological Station for the preservation of marine animals.

(*The British Association Table*).—During the past year, two naturalists have occupied the British Association table, viz., Mr. Francis G. Penrose and Mr. Allen Harker. These gentlemen have furnished reports of the investigations undertaken by them during their occupancy of the table, in accordance with the requirements of this Committee. These reports will be found appended below; and it is gratifying to note that interesting results outspringing from the studies there specified will, in all probability, be published shortly.

Application has been made for the use of the table, during the coming year, by Mr. Patrick Geddes, by whom important results, from a previous short occupation of this table, in 1879, have already been published. Mr. Geddes is now desirous of prosecuting certain special investigations; these will extend over a longer period, and Mr. Geddes will be accompanied by an assistant, whose services are rendered necessary by the nature of the investigations about to be undertaken.

With the foregoing facts and details before them, your Committee would most strongly urge the renewal of the grant for the ensuing year. They would further recommend that the amount be increased to 90*l.*, in consideration of the additional advantages now afforded to the occupier of a table, as specially mentioned in the last report.

I. *Report on the Occupation of the Table by Mr. Allen Harker.*

By the kind permission of the Committee, I occupied the British Association's table, at the Zoological Station, at Naples, from the 14th Feb. to the 20th May, 1881. For the first few weeks I devoted my attention to a general study of the comparative Morphology of the organs of circulation and respiration in the Polychætous Annelids, more especially in the sedentary forms (Tubicola). I then confined myself to the examination of one particular group, the family *Maldanidæ*, and the closely allied *Ammocharidæ*, and continued my researches on these families, as represented in the Bay of Naples, during the remainder of my stay. I studied the histology of the remarkable coloured bands (*ceintures* of Claparède) which adorn some of the anterior segments in the various species of *Maldanidæ*, with a view to tracing their relation (if any) to the function of respiration. With that object I made some 2,000 sections, and prepared a large amount of material, which I am still engaged in working out. The results I purpose publishing as soon as they are completed. The frequent occurrence in the Bay of the singular *Ammochares fusiformis*, Della Chiaja, and its close relationship with the *Maldanidæ*, led me to make a careful study of it, in the hope of elucidating some points in its anatomy which had been left incomplete by Claparède. I succeeded in tracing the nervous system, in continuous sections of the whole animal, which had (by that method) escaped the notice of the illustrious author of 'Les Annelides du Golfe de Naples.' The advantage of having so large a supply of this species enabled me to examine some thousands of specimens, and to note some interesting variations in the form of the branchial apparatus: these, too, I hope to make public shortly, together with drawings of the special features observed.

I had a further opportunity of studying the habits of *Phyllochætopterus pergamentaceus*, and extending the observations of Claparède on the structure of its tubes. I was (during the whole of my stay) kept supplied with abundant material, which is so indispensable to the study of my subject.

In addition to the opportunity afforded of carrying out my studies under the most favourable and perfect of conditions, I am indebted to my visit to the Station for much valuable knowledge of new and improved methods of manipulation in biological research, which cannot fail to be of lifelong service. An opportunity of putting some of that knowledge to a very practical use has been afforded me since my return, in fitting up a small biological laboratory, at the Royal Agricultural College, at Cirencester, where I have been largely guided by my Naples experiences.

While it would be merely superfluous to add one word in praise of the Station, I should fail in my duty were I not to record my deep gratitude for the uniform and kindly assistance rendered by the whole of the staff, and for the great interest which Professor Dohrn took in my work, and the very valuable advice and assistance he was ever ready to afford me.

For the permission to occupy the table I beg to tender my sincere thanks.

II. *Report on the Occupation of the Table by Mr. Francis G. Penrose.*

I asked for permission to use the British Association's table at the Zoological Station at Naples, so that, as I was obliged to leave England by medical advice at the beginning of this year, for three months, I might, if possible, employ a portion of my time in endeavouring to get some practical idea of general marine zoological work, especially with reference to the numerous invertebrate larval forms: their mode of capture, appearance, and the means in use at the Station of preserving them and showing their structure. The only point which I proposed to myself for special investigation was the vascular system of Lamellibranchs, which had been suggested to me by Professor Lankester in connection with *Solen legumen.*

Many eminent naturalists—as Lacaze-Duthiers, Agassiz, Langer—have studied the subject, and have demonstrated many points, both in the general course of the circulation and the channels through which the blood passes. In doing so they have almost invariably had recourse to artificial injection, which, though it has shown a great deal of much importance, has not proved entirely successful, probably because the arterial and venous portions of the circulatory system appear not to be connected by definitely-walled capillary passages, but that the blood finds its way, after leaving the arteries, amongst and between the various tissues and organs of the body, and is only re-collected into true sanguiniferous tubes near the great vena cava.

So that further investigation was still necessary, to decide such questions as to whether any blood passes into the cavity of the pericardium; and, if so, what becomes of it? Whether the apertures which connect the vascular system with the exterior are only for the inception of external fluid; or whether, under any circumstances, liquid contained in the vessels is able to pass outward through them? In fact, whether the liquid which is so copiously thrown out by a Lamellibranch, on contraction, consists of blood, or of any portion of the blood-fluid? *Solen legumen* seemed to be particularly favourable for the study of these questions, as the blood of this animal, besides possessing ordinary colourless corpuscles, is particularly rich in bright red corpuscles, discovered by Professor Lankester, and shown by him to contain hæmoglobin, which forms a perfectly natural injection; and, as will be seen from what has been said above, this is a point of very great importance. Unfortunately, notwithstanding the exertions made to obtain for me as many individuals of this species as possible, but very few were forthcoming, and those were nearly all full-grown, which were not very suitable, owing to the want of transparency and to the practical difficulties of manipulation,—the slightest injury rendering the individual useless for the research. But, from what I saw in them, I venture to think that, had it been possible to obtain younger specimens, they would have enabled me to settle those questions I was hoping to answer. As a definite result, I consider that (at any rate, in the only individual that allowed me a favourable examination) there were not any red corpuscles in the cavity of the pericardium, excepting, of course, those contained within the heart. In conclusion, I have to thank the staff at the Station for the constant facilities and assistance they afforded me.

III. *A List of the Naturalists who have worked at the Station from the end of June*, 1880, *to the end of June*, 1881.

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
146	Prof. Emery . .	Italy . .	July 21, 1880	Nov. 11, 1880
147	Cand. Köster . .	Bavaria . . .	Aug. 24 „	Oct. 12 „
148	Prof. Gasco . .	Italy . . .	Sept. 1 „	„ 25 „
149	Prof. Graf Solms-Laubach	Strasburg . .	„ 2 „	„ 12 „
150	Dr. Gaule . .	Saxony . .	„ 10 „	„ 12 „
151	Prof. Salensky. .	Russia . .	„ 24 „	June 11, 1881
152	Prof. Kroneker .	Berlin Academy .	„ 24 „	Oct. 29, 1880
153	Dr. G. Colasanti .	Italy . . .	„ 27 „	„ 29 „
154	Dr. Weyl . .	Berlin Academy .	Oct. 10 „	Mar. 16, 1881
155	Prof. R. Kossmann .	Baden. . .	„ 15 „	
156	Herr G. M. Bedot .	Switzerland .	Nov. 6 „	„ 27 „
157	Dr. G. C. J. Vosmaer	Holland . .	„ 26 „	Feb. 19 „
158	Dr. A. Della Valle .	Italy . . .	Jan. 1, 1881	
159	Dr. A. Andres .	Italy . . .	„ 1 „	
160	Barone R. Valiante .	Italy . . .	„ 1 „	
161	Mr. F. G. Penrose .	British Association	„ 28 „	Mar. 23 „
162	Mr. W. H. Caldwell.	Cambridge . .	Feb. 2 „	
163	Dr. Ulianin . .	Russia . .	„ 5 „	June 11 „
164	Mr. Allen Harker .	British Association	„ 12 „	May 21 „
165	Dr. Carl Friedländer	Prussia . .	„ 17 „	Mar. 10 „
166	Dr. J. W. van Wyhe	Holland . .	„ 27 „	June 11 „
167	Dr. J. Carrière .	Strasburg . .	March 7 „	April 23 „
168	Dr. E. Zacharias .	Hamburg . .	„ 7 „	„ 23 „
169	Dr. J. Brock . .	Bavaria . .	„ 7 „	„ 27 „
170	Prof. W. Flemming.	Prussia . .	„ 8 „	„ 21 „
171	Dr. v. Mereschkovsky	Russia . .	April 21 „	
172	Dr. J. MacLeod .	Belgium . .	March 9 „	
173	Dr. C. Chun . .	Saxony . .	„ 13 „	„ 23 „
174	Prof. Selenka . .	Würtemberg .	„ 15 „	„ 24 „
175	Dr. Griesbrecht .	Prussia . .	April 2 „	
176	Prof. Ed. van Beneden	Belgium . .	„ 5 „	
177	Cand. E. Göldy .	Switzerland .	„ 8 „	
178	Dr. H. Kraepelin .	Hamburg . .	„ 19 „	June 3 „
179	Professor v. Kock .	Darmstadt . .	May 23 „	

IV. *A List of Papers which have been published from August*, 1878, *up to the end of* 1880 *by the Naturalists who have occupied Tables at the Zoological Station.*

Professor Salenski . Études sur les Bryozoaires entoproctes. 'Ann. Scienc. Nat.' 6 sér. t. 5, 1877.

Mr. M. Marshall . The Morphology of the Vertebrate Olfactory Organ. 'Quart. Journ. Micr. Science,' vol. xix.

Professor Merkel . Ueber die Endigungen der sensiblen Nerven in der Haut der Wirbelthiere. Rostock, 1880.

Mr. A. Waters . On the Bryozoa of the Bay of Naples. 'Ann. and Mag. Nat. Hist.' vol. iii.

Professor Grenacher Untersuchungen über das Sehorgan der Arthropoden. Göttingen, 1879.

Professor Ulianin .	Sur le genre Sagitella. 'Arch. Zool. Expérim.' t. 7.
Professor O. Schmidt	Zusatz zu Dr. Keller's Aufsatz über neue Cœlenteraten aus dem Golf von Neapel. 'Arch. f. Mikr. Anat.' Bd. 18.
Dr. Falkenberg .	Ueber eudogene Bildung normaler Seitensprossen in der Gattungen Rytiphlœa, etc. 'Nachr. Kön. Ges. Wiss.' Göttingen, 1879.
Dr. Gabriel . .	Ueber primitives Protoplasma. 'Ber. Schles. Gesellsch.' 1878.
Mr. G. Bullar . .	On the Development of the Parasitic Isopoda. 'Phil. Trans. Roy. Soc.' 1878.
Mr. F. M. Balfour .	Monograph on the Development of Elasmobranch Fishes. London, 1878.
Professor Eimer .	Versuche über künstliche Theilbarkeit von Beroe ovata. 'Arch. f. Mikr. Anat.' Bd. 17.
Dr. E. Taschenberg	Helminthologisches Zeitsch. f. d. ges. Naturwissensch, 1878.
„ . .	Beiträge zur Kenntniss ectoparasit. mariner Trematoden. 'Abh. Naturf. Ges.' Halle, 1879.
„ . .	Didymozoon, eine neue Gattung in Cysten lebender Trematoden. Ibid.
Dr. A. Lang . .	Die Dotterfurchung von Balanus. 'Jenaische Zeitschr.' Bd. 12.
„ . .	Die Metamorphose der Nauplius-Larven von Balanus, etc. 'Mittheil. d. Aarg. Naturf. Ges.' 1878.
„ . .	Untersuchungen zur vergl. Anatomie u. Hist. des Nervensystems der Plathelminthen. I. 'Mittheil. Zoolog. Station, Neapel,' Bd. 1.
Professor Schmitz .	Ueber den Bau der Zellen bei den Siphonocladiaceen. 'Sitz.-Ber. niederrh. Ges. f. Nat. u. Heilk. zu Bonn,' 1879.
„ . .	Untersuchungen über die Zellkerne der Thallophyten. Ibid.
„ . .	Untersuchungen über die Structur des Protoplasmas und der Zellkerne der Pflanzenzellen. Ibid. 1880.
„ . .	Bildung der Sporangien bei der Algengattung Halimede. Ibid.
Dr. C. Chun . .	Die im Golf von Neapel erscheinenden Rippenquallen. 'Mittheil. Zool. Station, Neapel.' Bd. 1.
„ . .	Die Ctenophoren des Golfs von Neapel und der angrenzenden Meerestheile. 'Fauna u. Flora d. Golfs v. Neapel,' herausg. v. d. Zool. Station. Leipzig, 1880.
Professor E. Metschnikoff	Spongiologische Studien. 'Zeitschr. f. wiss. Zool.' Bd. 32.
„ . .	Ueber die intracelluläre Verdauung bei Cœlenteraten. 'Zool. Anzeiger,' 1880.
„ . .	Bericht über seinen Aufenthalt im Auslande (russisch). Odessa, 1880.
Prof. v. Rougemont.	Ueber Helicopsyche. 'Zool. Anzeiger,' 1878.
Prof. C. Emery .	La Cornea dei Pesci Ossei. Dal 'Giorn. di Scienze Nat. ed Econ.' Palermo, 1878.
„ . .	Contribuzioni all' Ittiologia. Reale Accad. dei Lincei, 1878.
„ . .	Le Specie del genere Fierasfer nel Golfo di Napoli. 'Fauna u. Flora d. Golfs v. Neapel,' herausg. v. d. Zool. Station. Leipzig, 1880.
Dr. v. Ihering . .	Beiträge zur Kenntniss der Nudibranchien des Mittelmeeres. 'Malakozool. Blätter,' N. F. Bd. 2.
„ . .	Graffilla muricicola, eine parasitische Rhabdocœle. 'Zeitschr. f. wiss. Zool.' Bd. 34.
Mr. Percy Sladen .	On a Remarkable Form of Pedicellaria, etc. 'Ann. and Mag. Nat. Hist. 1880.'
Dr. A. A. W. Hubrecht	Vorläufige Resultate fortgesetzter Nemertinen-Untersuchungen. 'Zool. Anzeiger,' 1879.
„ . .	The Genera of European Nemerteans critically revised. 'Notes Leyden Mus.' 1879.
„ . .	Vorloopig Overzigt natuurh. Onderzoek, etc. in het Zool. Stat. te Napels, etc. Leyden, 1879.
„ . .	Zur Anatomie u. Physiologie des Nervensystems der Nemertinen. 'Naturk. Verh. d. Koninkl. Akad.' Deel. XX.

Dr. W. Hubrecht .	The Peripherical Nervous System in Palæo- and Schizo-Nemertini, one of the layers of the body-wall. 'Quart. Journ. Micros. Sc.' 1880.
,, . .	Het peripherisch Zenuwstelsel der Nemertinen. 'Tidschr Ned. Dierk. Vereen.' Deel V.
Dr. Della Valle .	Sui Coriceidi Parassiti e sull' Anatomia del genere Lichomolgus. 'Mittheil Zool. Station, Neapel,' Bd. 2.
Mr. P. Geddes . .	Sur la Chlorophylle animale. 'Arch. Zool. Expérim.' t. 8.
,, . .	Observations sur le Fluide périviscéral des Oursins. Ibid.
Dr. A. Andres . .	Intorno all' Edwardsia Claparedii. R. Accad. d. Lincei, 1879.
Dr. Berthold . .	Zur Kenntniss der Siphoneen und Bangiaceen. 'Mittheil. Zool. Station, Neapel,' Bd. 2.
Dr. Solger	Neue Untersuchungen zur Anatomie der Seitenorgane der Fische. I. Die Seitenorgane der Chimæra. 'Arch. f. Mikrosk. Anat.' Bd. 17. II. Die Seitenorgane der Selachier. Ibid. III. Die Seitenorgane der Knochenfische. Ibid. Bd. 18.
Dr. Keller . .	Zur Entwicklungsgesch. der Chalineen. 'Zool. Anzeiger,' 1879.
,, . .	Studien über Organisation u. Entwicklung der Chalineen. 'Zeitschr. f. wiss. Zool.' Bd. 33.
,, . .	Neue Cœlenteraten aus dem Golf von Neapel. 'Arch. f. Mikr. Anat.' Bd. 18.
Professor Selenka .	Keimblätter und Organanlage bei Echiniden. 'Sitzber. d. Physik. Med. Soc.' Erlangen, 1879.
,, . .	Keimblätter und Organanlagen der Echiniden. 'Zeitschr. f. wissensch. Zool.' Bd. 33.
Professor O. u. R. Hertwig	Die Actinien anat. u. histol. mit bes. Ber. des Nervensystems untersucht. Jena, 1879.
Professor v. Koch .	Bemerkungen über das Skelet der Korallen. 'Morphol. Jahrbuch,' Bd. 5.
Dr. V. Mereschkowski	Sur la Structure de quelques Coralliaires. 'Comptes Rendus,' 1880.
,, . .	Sur l'Origine et le Développement de l'Œuf chez la Méduse Eucope avant de la fécondation. Ibid.
Professor F. Todaro	Sui primi Fenomeni dello Sviluppo delle Salpe. 'Reale Accademia d. Lincei,' 1880.
Professor A. Götte .	Bemerk. zur Entw.-Gesch. der Echinodermen. 'Zool. Anzeiger,' 1880.
,, . .	Ein neuer Hydroidpolyp. Ibid.
Dr. W. Vigelius .	Vorloopig Verslag van de Werkzamheden, etc. (Cephalopoden-Anatomie.)
,, . .	Ueber das Excretionssystem der Cephalopoden. 'Niederl. Archiv.' 1880.
,, . .	Untersuchungen an Thysanoteuthis rhombus. 'Mittheil. Zool. Station Neapel,' Bd. 2.
Prof. G. Duplessis .	Observations sur la Cladocoryne flocconeuse. Ibid.
,, . .	Catalogue provis. des Hydroïdes médusipares, etc. Ibid.
,, . .	Hydroïdes médusipares du Golfe de Naples. 'Bull. Soc. Vaud.' 2e sér. vol. xvii.
Dr. Brock . .	Versuch einer Phylogenie der dibranchiaten Cephalopoden. 'Dissert. Morphol. Jahrbuch,' Bd. 6.
Dr. A. Batelli . .	Istolog. della Pelle dei Pesci Teleostei. 'Rivista Scientifica-Industr.' Firenze, 1880.
Dr. Foetinger . .	Sur la Découverte de l'Hémoglobine dans le système aquifère d'un Echinoderme. 'Bull. Acad. Roy. Belg.' 2e sér. t. 49.
,, . .	Sur l'Existence de l'Hémoglobine chez les Echinodermes. 'Archives de Biologie,' vol. i.
Dr. J. W. Spengel .	Die Geruchsorgane und das Nervensystem der Mollusken. 'Zeitschr f. wissensch. Zool.' Bd. 35.
Prof. C. Hoffmann .	Vorläufige Mitth. zur Ontogenie der Knochenfische. 'Zool. Anzeiger,' 1880.
Dr. Ludwig . .	Die Bildung der Eihüllen bei Antedon rosacea. Ibid.

Dr. E. Yung . Sur l'Action des Poissons chez les Céphalopodes. 'Comptes Rendus,' 1880.

" . . De l'Influence de Milieux alcalins ou acides sur les Céphalopodes. Ibid.

" . . De l'Influence des Lumières colorées sur le Développement des Animaux. Ibid.

" . . —— 'Mitth. Zool. Station, Neapel,' Bd. 2.

V. *A List of Naturalists to whom Specimens have been sent from the end of June,* 1880, *to the end of June,* 1881.

					Lire
1880.	June	23	Prof. Weismann, Freiberg, i. B.	Hydroida	120
	"	23	F. von Czeschka, Gratz	Cephalopoda	10
	"	29	Professor Kühne, Heidelberg	Fish-eyes	28
	July	19	Dr. Krukenberg, Heidelberg	Amphioxus	27
	"	19	Musée Royal, Brussels	Various classes	510
	"	19	Senator Romer, Hildesheim	Select preparations	—
	"	19	Naturw. Cabinet, Stuttgart	Select preparations	—
	"	19	Prof. E. K. Hoffmann, Leyden	Material for dissection	260
	Aug.	3	Prof. Lankester, London	Pontobdella, Amphiglena	19·45
	"	3	Dr. E. B. Aveling	Various classes	38·35
	"	3	Prof. F. Jeffrey Bell, London	All classes	37·70
	"	14	Prof. Kühne, Heidelberg	Eyes of Mustelus	3
	"	14	Dr. Spengel, Göttingen	Chiton. Ostrea	—
	"	19	Prof. Weismann, Freiberg, i. B.	Hydroida	13·25
	"	31	Zool. Institut, Heidelberg.	Various classes	219·19
	"	31	Dr. Fraisse, Tutzing.	Gastropoda	8·10
	Sept.	11	Dr. W. Lecke, Stockholm	Various classes	49·33
	"	11	Prof. A. M. Marshall, Manchester	All classes	652·19
	"	18	P. de Loriol, Châlet des Bois	Echinodermata	20·5
	Oct.	20	Naturh. Museum, Hamburg	Various classes	242
	"	23	Zoolog. Museum, Hanover	Ctenoph., Echinod., Crustacea	155
	"	23	Dr. Eger, Vienna	All classes.	152
	"	27	Dr. Graeffe, Zool. Station, Trieste	Living Amphioxus	7·50
	Nov.	8	Dr. Spengel, Göttingen	Vermes	—
	"	8	Prof. von Siebold, Munich	Argentina	16·20
	"	11	Prof. Emery, Cagliari	Select preparations	112·50
	"	12	Nicolai-Gymnasium, Leipzig	All classes	93
	"	12	H. N. Moseley, London	Alcyonium	17·50
	"	12	Senator Römer, Hildesheim	Fishes	136
	"	23	Prof. Steindachner, Vienna	Fishes	105
	"	23	Prof. Plateau, Ghent	Hydromedusa	211·50
	"	27	Prof. Ehlers, Göttingen	Toxopneustes	79
	"	29	Naturh. Museum, Schaffhausen.	Various classes	150·55
	Dec.	7	Prof. Grenacher, Rostock	Eyes of Cephalopoda	18·75
	"	12	Dr. W. F. Vigelius, Dordrecht	Cephalopoda	67·10
	"	19	E. Graebke, Potsdam	Coelent., Echinod., Crustacea	18·20
	"	20	Dr. Eger, Vienna	Various classes	86·5
	"	21	Kgl. Gymnasium, Leipzig	All classes	186·16
	"	31	Liceo Genovesi, Naples	Elementary collection	130
1881.	Jan.	9	Prof. van Beneden, Lüttich	Ascidiæ	158·33
	"	9	Prof. von. Siebold, Munich	Ophiura	10·
	"	9	Prof. T. J. Parker, New Zealand	All classes	328·88
	"	9	Rev. A. M. Norman, Durham	Crustacea	233·97
	"	9	Zoolog. Institut, Strasburg	Mollusca	16
	"	17	Dr. Eger, Vienna	Various classes	86·80
	Feb.	16	E. Graebke, Potsdam.	Mollusca	23
	"	17	Dr. Everts, Haag	Cestum	7
	"	17	University, Leyden	Ascidiæ	—
	"	23	Balt. Verein f. Thierzucht, Griefswald	Various classes	—

				Lire
1881.	Feb. 28	Kgl. Cadetten-Corps, Munich	Elementary collection	75
	April 9	Höhere Bürgerschule, Dordrecht	Coelent., Echinod.	89·75
	„ 28	Prof. Ausserer, Staats Gymnasium, Gratz.	Elementary collection	134·23
	„ 28	Fric, Naturalienhändler, Prague	Various classes	53·5
	„ 28	Prof. Eimer, Tübingen	Annelida, Coelenterata	162·95
	„ 28	Dr. Chun and Dr. Fraisse, Leipzig	Various classes	129·73
	May 4	Prof. van Beneden, Lüttich	Select preparations	402·25
	„ 12	M. Goeldi, Schaffhausen	Various classes	34·85
	„ 12	Prof. Cattie Arnhem, Holland	Selachii	57·50
	„ 12	Dr. Carpenter, London	All classes	265·85
	„ 13	Zoolog. Institut, Leipzig	Cephalopoda, Echinodermata	331·75
	„ 13	Dr. Taschenberg, Halle	Various classes, for anatomy	68·50
	„ 21	Rev. A. M. Norman, Durham	Echin., Crust., Sponges	152·82
	„ 21	Zool. Institut, Giessen	Various classes, for anatomy	164·5
	„ 21	Zool. Institut, Wurzburg	Various classes, for anatomy	132·15
	„ 21	Prof. Weismann, Freiberg, i. B.	Hydroida	2·85
	June 2	Dr. Eger, Vienna	Coelent., Vermes	37·97
	„ 2	Prof. Butschli, Heidelberg	Amphioxus, Hippocampus	17·66
	„ 2	Prof. Dames, Berlin	Heads of Fishes	27
	„ 6	Dr. E. B. Aveling, London	Various classes	150·93
	„ 6	H. N. Moseley, London	Various classes	825·
	„ 10	Naturhist. Museum, Hamburg	All classes, except Mollusca	246·73
	„ 14	C. Günther, Berlin	Radiolaria	4
	„ 14	F. M. Balfour, Cambridge	Various	102·40
				8492·57

VI. *A List of Naturalists to whom Microscopic Preparations have been sent from the end of June,* 1880, *up to June,* 1881.

				Lire
1880.	July 1	Prof. Fürbringer, Amsterdam	12 preparations	35·75
	Nov. 30	A. Myèvre, Nice	20 „	44·50
	Dec. 2	Dr. A. Valle, Trieste	15 „	31·50
1881.	Feb. 16	Dr. Guida, Naples	2 „	2·50
	„ 26	Maurice Bedot, Geneva	2 „	3·
	March 5	L. Dreyfus, London	all anatomical preparations	563·50
	„ 10	Percy Sladen, Halifax	28 preparations	60·
	„ 11	Prof. L. von. Schmarda, Vienna	62 „	144·25
	„ 11	Prof. Berlin, Amsterdam	59 „	131·50
	„ 11	Prof. Salensky, Kasan	33 „	73·0
	—	Dr. Vigelius, Dordrecht	7 „	17·
	11	Prof. Huxley, London	49 „	118·50
	„ 12	Prof. Heller, Innsbruck	25 „	58·75
	„ 12	Prof. Waldeyer, Strasburg	12 „	27·64
	„ —	Prof. Ausserer, Gratz	28 „	60·
	April 11	Prof. van Bambeke, Ghent	68 „	157·
	„ 23	Prof. Emery, Bologna	59 „	134·50
	„ 26	Wallroth & Co., London	124 „	259·75
	„ 27	Prof. Schneider, Breslau	76 „	150·75
	May 6	Prof. E. van Beneden, Liège	50 „	119·
	„ 6	Prof. P. van Beneden, Louvain	50 „	119·
	„ 27	Dr. Bouvin, Utrecht	4 „	8·
	„ 30	Zoolog. Institut, Budapest	28 „	60·
				2377·39

Report of the Committee, consisting of Mr. J. A. Harvie Brown, Mr. John Cordeaux, *and* Professor Newton, *appointed at Swansea for the purpose of obtaining (with the consent of the Master and Brethren of the Trinity House, and of the Commissioners of Northern Lights) observations on the Migration of Birds at Lighthouses and Lightships, and of reporting on the same, at York, in* 1881.

Printed schedules for filling in observations, accompanied by letters of instruction (similar to those laid on the table), were issued by Mr. Cordeaux and Mr. Harvie Brown to 83 stations on the east coast of Scotland and England and the Channel Islands, a large proportion of these being light-vessels, situated far from land in the North Sea.

On the west coast of Scotland and the Western Isles, including the Isle-of-Man, Mr. Harvie Brown supplied papers to 38 stations.

And on the West Coast of England Mr. Philip Kermode, of Ramsey, Isle-of-Man (whose kind assistance the Committee desire gratefully to acknowledge), issued papers to 39 lighthouses and lightvessels.

Altogether the stations from which co-operation was asked number 160.

From these, returns have been received from 103, namely: east coast stations, 46; west coast stations, 57. From several stations letters have also been received, stating that the scarcity, or total absence of birds, has prevented any return being sent in.

Schedules, letters of instructions, were also forwarded, through Mr. Alexander Buchan (Secretary, Scottish Meteorological Society, Edinburgh) to three stations, two in Iceland and one in Faroe. A fourth, more northern station, is secured on Fair Island for 1881, Mr. William Lawrence having kindly undertaken the work. The Faroe station has failed this year, but the Committee hope better things from it next.

The Committee have also made arrangements with Mr. Alexander Goodman More, of Glasnevin, Dublin, and Mr. Richard M. Barrington, of Fassaroe, Co. Wicklow, to undertake the working of the Irish coast in 1881, and beg leave to suggest that these gentlemen, as well as Mr. Philip Kermode, before mentioned, and Mr. James Hardy, of Old Cambus, Berwickshire (who has rendered great assistance to the Committee in the Scotch stations), be added to the Committee, should it be re-appointed.

Great credit is due to the various observers for the careful and painstaking manner in which the greater proportion of the returned schedules have been sent in. The observations taken are a decided improvement on those of the preceding year, when the men were new to the work; and they exhibit generally, in a marked degree, the intelligent interest taken in the inquiry. The work, it must be remembered, is entirely voluntary, and often carried on under circumstances of considerable difficulty and discomfort.

The Committee beg to express their best thanks to the Master and Elder Brethren of the Trinity House, and the Commissioners of Northern Lights, for their ready co-operation and assistance, through their officers and men, in the inquiry. Indeed, without the help thus afforded, the observations could never have been obtained.

The best returns, as might have been expected, have been sent in from isolated stations, at lighthouses on islands and skerries off the coast, as well as from the lightvessels. Lighthouses situated some distance inland, or surrounded by houses, make few returns, or none.

In presenting their report, your Committee are aware that the inquiry is as yet in its infancy. Their work, so far, has been mainly to collect and tabulate sufficient data, from which they have every reason to expect that, at some future time, reliable facts may be deduced on the migratory movements of birds in their spring and autumn migrations. The results of the observations taken so far, in 1879 and 1880, have proved so satisfactory and unexpected that the Committee have been able, with tolerable certainty, to arrive at the following conclusions:—

On the east coasts of England and Scotland, as in 1879, the main line of migration has been a broad stream from east to west, covering the whole of the English and Scotch east-coast; this is the line mainly followed by the *Passeres*. Taking this line as a basis, we find birds also occasionally coming from points north of east, but, in the vast majority of instances, the migration has had a decidedly southerly trend, coming from points south of east, and even direct from the southward. In 1879 the main body of immigrants crossed at the most southern stations, at the narrowest parts of the North Sea, and direct into our south-eastern counties; in 1880 the main body has been tolerably equally divided between the mid and south-eastern counties. During the principal month of migration, October, the wind blew persistently, day by day and week by week, from northerly and north-easterly quarters, and to this cause we may fairly attribute, to some extent, the deflection of migrants to the south; on the north-east coast of England and the stations on the east-coast of Scotland birds are reported as comparatively scarce, and in some instances absent altogether. A reference to the meteorological charts in the 'Times' shows that, in the autumn of 1880, the prevailing winds and gales were from the east and north-east, and while these winds do not appear to have compressed the horizontal lines so much as the north-westerly did, in 1879, the birds appear to have passed at greater elevations and, in many cases, to have been borne far to the westward of these islands. The migration does not appear to have come in such great throbs or 'rushes' in 1880 as in 1879, but to have been more dispersed and more regular; this, no doubt, is a natural consequence of the waves being more spread out in 1880 than in 1879.

Independent of the broad stream of immigrants coming directly from the east, there is, in the autumn, always a steady stream of migrants which closely follow the coast-line from north to south, composed of birds either moving from more northerly districts of our islands, or of such immigrants coming from the east as strike the coast in more northern latitudes, and then follow it to the south. The great E. to W. stream of migration is mainly composed of some few well-known species, which regularly come to us in the autumn, the great body undoubtedly remaining to winter. Placed in order of rotation, according to their numerical superiority or otherwise, we find the *Skylark*, *Starling*, *Hooded Crow* and *Rook*, the *Song Thrush*, *Blackbird*, *Fieldfare* and *Redwing*; and then *Sparrows* (both the common species and tree-sparrow), and *Linnets*, and *Chaffinches* compose the bulk of the immigrants. Others, as the *Redstart*, *Wheatear*, *Whinchat* and *Stonechat*, and other soft-billed insect-eaters, although coming from the eastward, after striking the coast, persistently follow the shore-line to the south. All the waders and other shore-birds, as well as *Geese*, *Ducks*, *Divers*, and *Gulls*, and sea-fowl generally, move from north to south—cutting the line of the *Passeres* at right angles. As a rule, the sea-fowl migrate some distance out at sea, the waders along the coast. Although, as yet, the Committee have no stations, except Heligoland, on the European side of the North Sea, it may fairly be presumed that there is similarly another stream of birds passing down the coast-line of Europe. Migration, as observed on that island for many years, by that veteran ornithologist, Herr Gätke, points to the undoubted fact that the line followed by birds is, as a rule, from E. to W., and doubtless some portion of these Heligoland birds keep moving westward or south-westward till, eventually, they strike our east coast. There are, however, many species which appear to make Heligoland the western boundary of their autumn wanderings, and crossing, as they do, that island in enormous numbers, must eventually follow the coast-line to the south, for the simple reason that they never occur on our own coast, except as very rare and occasional wanderers. Such are the *White-Wagtail* and *Blue-headed Wagtail* of the Continent, the *Blue-throat*, *Ortolan*, *Lapland Bunting*, *Richard's Pipit*, and, in a less degree, the *Pied-flycatcher* and *Shore-lark*. These, then, must all pass southward along the European coast, as do, doubtless, an immense majority of those countless *Sparrow-hawks*, *Siskins*, and more familiar birds, which cross that island in the autumn migration; and just as, occasionally, some species, whose line of migration lies further eastward still, turn up on the old rock as wanderers from the regular track, so do, occasionally, now one and now another of the regular Heligoland immigrants get blown across to our side.

The observations taken at some of the southern stations, in 1879 and 1880, show that, in the autumn, there is what may be called a double stream of birds, crossing each other near the entrance to the English Channel, that is, from the Essex and Kent coast towards the S.E. on the French and Belgian coast, and again, in the opposite direction, from Belgium to the coast of Kent. During the severe weather in the early part of December, 1880, flocks of birds came to us direct from the French coast, or from S. to N. These latter must be considered purely local migrations, caused by sudden outbursts of severe weather.

It is a curious fact that, in nearly every case of birds passing the Casquets off Alderney, in the past autumn, they were travelling in a N.W. direction, or from the French to the English coast, a line of migration which does not seem to be in proper accord with that we should imagine migrating birds would, or rather ought to, take. On reference to the chart of the Channel, it is apparent that any flocks leaving the French coast at or near Cape de la Hogue, and crossing Alderney, when once off the Casquets, might as readily and easily steer their course for the Start Point, on the English side, as across the wide break in the French coast for Port Sillon, each being about equal distances from the Casquets. Not the least interesting portion of the full report refers to the large flocks of birds seen during the autumn of 1880 far out over the Atlantic. The great easterly gales, continuing for weeks together over the Atlantic and North of Europe, so disastrous to our shipping, undoubtedly carried many migrants far to the westward, and the mortality amongst them must have been very great indeed, to judge from the few records that have arrived from seagoing vessels. These gales have also, no doubt, affected the direction of the migration to a considerable extent, and indications of this agency may be found in the occurrence, on our shores, of many rare wanderers, in the autumn of 1880.

Notwithstanding the enormous number of immigrants arriving, as shown in the schedules returned from each station, it is quite certain that these returns only represent an almost inappreciable percentage of the actual number on passage. On days of uncertain light, or on clear, fine, starlight nights, when migration is carried on at a considerable height, immense numbers of birds might pass any of the stations for hours without being observed; and it is quite possible that, if the whole 300 miles of the east-coast line of England were studded with floating posts of observation at the distance of half-a-mile, equal average results would have been obtained; the present stations on the light-vessels affording no more especial line of advantage than any other imaginary line drawn across the North Sea.

As, in 1879, birds have crossed at all hours of the day and night, and in all winds and weathers. The returns also show, as did the preceding, that they seldom fly dead to windward, except with very light breezes, and that strong opposing winds are invariably prejudicial to their passage. The line of flight mostly adopted is within three or four points of the wind; they will go on well with a beam-wind, or some points even aft of beam, if not too strong. Small weak-winged birds have often, as noticed on the light-vessels, great difficulty in making head against strongly-opposing winds. If the wind changes during the actual passage, birds have been observed to change the direction of their flight to suit the wind. Even the strong-winged wild geese and swans are observed, when well-up in the wind, to drift to one side a little, having the appearance of flying left shoulder first instead of head first.

Birds are noticed at the stations as sometimes flying high, sometimes low; often with northerly and easterly winds they fly high, and with winds in opposite quarters, low. The state of the weather at the time of migration has more, we think, to do with the height at which birds travel than the direction of the wind. On clear light nights they travel high, as a rule; but in fog, rain or snow, or in thick murky weather, low—not many feet above the waves. On thick dark nights, indeed, lost birds will wheel for hours round a light-vessel, but with the first break in the clouds, the stars appearing, or streak of early dawn, are on their course again to the nearest land. At times birds are seen passing high in air, almost beyond the ken of human vision, and when clouds or fogs rapidly lift or clear off during the time of migration, the said migration appears often to cease to mortal vision, indicating an ascent to a higher level. Birds are also known to descend upon Heligoland and the light-vessels almost perpendicularly from the sky, indicating a course of migration at a great height. The height at which birds travel in foggy weather, or in snow or rain, has probably a good deal to do with the various numerical returns of those killed at lanterns. Broadly speaking it is the brightest, whitest, fixed lights which, having most influence in penetrating fog or haze, attract the most birds. In 1877, at Skerryvore, in the month of October, the number of birds killed was 600, chiefly the common thrush and the ring-ousel. This year the mortality has been heavy at some of the light-vessels. At the Casquets, off Alderney, on October 7, from 11 P.M. to 3 A.M., S.S.E., rain, land-rails, water-rails, woodcocks, ring-ousels, song-thrushes, and swallows were seen around the light. Of these there struck the glass: one land-rail, one water-rail, four ring-ousels, and 100 swallows. At the Casquets, which is a revolving light, the larger birds follow the rays, but do not often strike the glass. Some of the reporters state extreme height above the sea, as a cause of birds seldom or never striking the glass, or being seen hovering around the light. Certainly returns show a preponderance of deaths first at light-vessels, whose average height above the sea is only a few feet; secondly, at such stations as the Bell-rock, Dhuheartach or Skerry-vore, whose lanterns are not higher than sixty or seventy feet above the sea.

With such favourable passages as light head-winds afford, the migrants are so little fatigued that they do not alight on reaching land, but keep on their course to the interior. At other times with adverse winds they drop on reaching the shore, being hardly able to struggle to land.

The observations show beyond doubt that all birds are migratory (if we except our common game-birds, and perhaps the green woodpecker). Even such comparatively weak-winged birds as the *gold-crested wren*, *common wren*, *the titmice*, *hedge-sparrow*, *common sparrow*, and *redbreast* change their locality, crossing the North Sea in large numbers. At Heligoland, Herr Gätke remarks (in the very comprehensive and highly interesting notes sent to us), 'Up towards the end of July, all young sparrows disappeared from the island,' and 'up to the middle of September nearly all old sparrows had quitted the island.' On October 10 there was 'an influx of fresh sparrows,' probably arriving from some more northern region.

As a rule, the young of the year migrate some weeks in advance of the old birds; this holds good with all orders and almost all species. In the spring the males often migrate in advance of the females. In spring, birds migrate, with rare exceptions, at night, and as the weather is then finer, and the nights shorter and clearer, do not fly low and run their heads so much against the lanterns of lighthouses and lightships. The spring migration is also carried on much more leisurely, migrants proceeding by easy slopes northward, and there are none of those great 'waves' or 'rushes' which are so characteristic of the autumn migration. The notes on spring migration taken in 1879 and 1880 point also to the conclusion that, at this season, migrants strike the glasses of lanterns from 11 P.M. to the dawn of day, the majority after midnight, and not also in the early hours of night, as is the case in the autumn.

It is remarkable how suddenly the stream of migration commences running, and how suddenly it stops again; it may be from 8 A.M. to 1 P.M. there is a continual stream of various migrants arriving on our coasts, and then, or at least for that day, migration is apparently over, and not another bird is seen.

The time of migration of any particular species extends over a considerable period. Sometimes it is over four or five weeks, in other cases going on for months or even half-a-year. Indeed, birds seem to be crossing the North Sea all the year round, and no sooner does the ebb of the autumn migration cease—and it is prolonged into February—than the flood sets in, and birds are passing northward again. In every case of normal migration, any given species will continue to pass day by day, or week after week, till it attains the maximum in a 'great rush,' the main body passing, and after this falls away, till the migration of that species ceases or is completed.

Independent of the normal or ordinary migration we have frequently local migrations, due to sudden changes of weather, or in search of fresh feeding-grounds. These 'great rushes' of immigrants coming helter-skelter on to our coasts, are, as will be seen from the Report, often accompanied, or followed very closely, with outbursts of severe weather; and a sudden increase of cold in winter will almost clear a whole district of birds.

In 1879 the maximum of immigrants crossed the North Sea between the 12th to the 23rd of October; in 1880, between the 15th and end of the same month; in both years, perhaps the greatest number on any given day on the 17th of the month. It is a curious fact that the stomachs of migratory birds on their first landing never contain any food.

This is as much as can be set forth in an abstract. A full and detailed account of the Migration of Birds in the Autumn of 1880, will be found in the General Report, which contains much interesting matter bearing on migration. It may be added finally, that in endeavouring to arrive at any conclusions regarding the causes of migrational phenomena in 1880, as set forth in the General Report, the Committee have taken more account of the vertical area of birds' flight in 1880 than in 1879, and have compared the effects of prevailing north-west winds in 1879 pressing laterally upon the lines of migration with those of 1880, which being easterly and north-easterly, have had the contrary effect of spreading out the migratory wave, or at least not deflecting it to the same extent, and also causing birds to migrate at greater elevations, and where the gales have been most severe to bear them away above the range of vision and carry vast numbers out to sea, until, weary and exhausted, they have ceased to be able to guide themselves, and involuntarily lowered, to be picked up senseless and stunned on board the ships, or to perish in thousands in the ocean. And, lastly, the Committee have hinted at the wideness of the migratory waves depending upon the pressure of the starting-points, or upon, perhaps, a larger north and south area occupied in the breeding season of 1880.

The data, however, are not yet sufficient, nor have the observations been carried on sufficiently long, to arrive at any positive conclusions as to the *how* and the *why* of the whole matter. The Committee must, therefore, for the present, be satisfied to say nothing more, but trust that the Association will enable it to continue the collection of facts.

Report of the Committee, consisting of Lieut.-Colonel GODWIN-AUSTEN, Dr. G. HARTLAUB, Sir J. HOOKER, Dr. GÜNTHER, Mr. SEEBOHM, and Mr. SCLATER, *appointed to take steps for investigating the Natural History of Socotra.*

THE debt due to Professor Balfour for the balance of the costs of the expedition (23*l.* 12*s.* 2*d.*), and the sum of 1*s.* 3*d.* for petty expenses, have been paid out of the sum of 50*l.* granted at the Swansea meeting, leaving a balance of 26*l.* 7*s.* 10*d.* in the hands of the Committee. This has been increased by the proceeds of the sale of the duplicate birds (7*l.* 10*s.*) and land shells (3*l.* 2*s.*), making a balance of 36*l.* 19*s.* 10*d.* now in the hands of the Committee for future operations.

The greater part of the zoological collection made by Professor Balfour has now been worked out, chiefly by the Assistants in the Zoological Department of the British Museum, to which institution the first complete series of zoological specimens of every class has been assigned.

The following reports on these collections have been published in the 'Proceedings' of the Zoological Society of London:—

1. On the Birds collected in Socotra by Professor I. Bayley Balfour. By P. L. Sclater and Dr. G. Hartlaub. 'P.Z.S.' 1881, p. 165.

2. On the Lepidoptera collected in Socotra by Professor I. B. Balfour. By Arthur G. Butler. 'P.Z.S.' 1881, p. 175.

3. On the Land Shells of the Island of Socotra, collected by Professor Bayley Balfour. By Lieut.-Colonel H. H. Godwin-Austen. Part I. 'P.Z.S.' 1881, p. 251.

4. Descriptions of the Amphisbænians and Ophidians collected by Professor I. Bayley Balfour in the Island of Socotra. By Dr. A. Günther. 'P.Z.S.' 1881, p. 461.

5. Notes on the Lizards collected in Socotra by Professor I. Bayley Balfour. By W. T. Blanford. 'P.Z.S.' 1881, p. 464.

6. On the Coleopterous Insects collected by Professor I. Bayley Balfour in the Island of Socotra. By Charles O. Waterhouse. 'P.Z.S.' 1881, p. 469.

7. On the Hymenoptera collected by Professor I. Bayley Balfour in Socotra. By W. F. Kirby. 'P.Z.S.' 1881, p. 649.

8. On the Land Shells of the Island of Socotra collected by Professor I. Bayley Balfour. By Lieut.-Colonel H. H. Godwin-Austen. Part II. Helicacea. 'P.Z.S.' 1881, p. 802.

The following are some of the more remarkable points touched upon in these reports:—

The Birds, reported upon by Mr. Sclater and Dr. Hartlaub, are found to belong to thirty-six species—generally 'North-east African in character, being mostly such as are included in Heuglin's "Ornithologie Nord-ost-Afrikas."' Six, however, are peculiar to the island, the most remarkable of them being a new form of sparrow with a very thick bill, which is named by Messrs. Sclater and Hartlaub *Rhynchostruthus socotranus*.

Mr. Butler's report on the Butterflies and Moths captured by Professor Bayley Balfour and his assistants in Socotra, tells us that of the thirteen species of which examples were brought, not less than seven were new to science. 'Of the new forms five are allied to previously-recorded types from the following localities:—one from the Comoro Islands, one from South-west Africa, one from Zanzibar, and two from Arabia. Without the help of these last two it would therefore have been impossible for anyone not acquainted with it to guess at the locality from which this collection had been obtained.'

The Reptiles collected by Professor Balfour in Socotra have been worked out by Dr. Günther and Mr. W. T. Blanford, Dr. Günther taking the Snakes and Amphisbænians, and Mr. Blanford the remaining Lacertilians. Both of these collections were found to be of considerable interest. Among the snakes is a new form allied to *Tachymenis*, which Dr. Günther has proposed to call *Ditypophis*, and a new species of *Zamenis* (*Z. socotræ*). Both these indicate an alliance with the circum-Mediterranean fauna. On the other hand the Socotran Sand-Asp (*Echis colorata*) belongs to an Arabian and Palestine species, while the Amphisbæna of Socotra (*Pachycalamus brevis*, gen. et sp. nov.) has its nearest allies in Eastern and Western Tropical Africa. Of the six species of lizards of which examples were in Mr. Blanford's series, three proved to be new to science.

As regards the Land Shells of Socotra, which are of special interest, we annex a special report upon this branch of the subject drawn up by Lieut.-Colonel Godwin-Austen, one of the Committee.

From this report and from what has been already stated, it will be obvious that, although the collections made by Professor Balfour were very small in each group—in some cases almost of a fragmentary character, the results in every case present features of great interest. It is obvious that, judging from what is thus known, Socotra must possess —what was thought scarcely probable by many at the time the scheme for exploring it was first started—an indigenous fauna of considerable extent, and well worthy of further investigation. As regards the flora of Socotra we have said nothing, because Professor Balfour, who has himself undertaken the investigation of the botanical collections, has not yet completed his task. But a preliminary examination has shown, we believe, that his series embraces about 150 absolutely new flowering plants, amongst which are from fifteen to twenty representatives of new genera—so that it is manifest that, like the fauna, the flora of Socotra possesses a strong autochthonous element.

Under these circumstances, we trust that the Committee for the investigation of the Natural History of Socotra may be re-appointed, with its sphere extended so as to embrace the adjoining highlands of Arabia and Somali-land, without the exploration of which it is not possible that a true understanding of the flora and fauna of Socotra can be arrived at; and that the sum of 200*l.* may be assigned to the Committee for this purpose.

APPENDIX.

Report on the Socotran Land and Freshwater Shells collected by Professor BALFOUR, *by* Lieut.-Colonel H. H. GODWIN-AUSTEN, *F.R.S.*

Since the last meeting of the British Association the land and freshwater shells of Socotra, which were assigned to me to work out, have been nearly all described, and quite come up to the expectations I was led to form of them at a first inspection. The Cyclostomaceæ were described in a paper which was read before the Zoological Society in February, 1881, illustrated by two plates; the Pulmonata, in June, also illustrated by two plates. In the first paper, we find that no less than seven species of *Otopoma* (Africo-Arabian) were brought home, of which four are quite new, viz., *O. balfouri*, *complanatum*, *conicum*, and *turbinatum*: *Tropidophora* (Madagascar-Rodriguez), two species, *T. socotrana* and *balfouri*: *Lithidion* (Arabia), one species, *L. marmorosum*, and a *Cyclotopsis* (Southern India—Seychelles), perhaps the most interesting form discovered by Professor Balfour in this island, which I have named *ornatus*. This is another example of the connection between Southern India on one side of the Arabian Sea and Africa on the other. The Pulmonata are more numerous and mostly belong to a sub-genus of the *Bulimuli*, *Achatinelloides*, Nevill, created for the very common Socotran shell *Bulimulus socotorensis* of Pfeiffer. All the allied species on the island I have put into this group until we know more about the land shells of the mainland near Cape Guardafui. We have altogether ten species in this genus; some of them very prettily marked forms. One group of *Bulimulus* is very peculiar, and in form and coloration approaches *B. velutinus*, Pfr., from the Seychelles Islands.

Of the genus *Ennea* we have one form already known, *passamiana*, Petit, and a new species which I have named after Professor Balfour.

Of the Stenogyridæ there are some fine shells; one elongate form, which is used as a pipe by the natives of the island, I have named *fumificatus;* the other species are *gollonsirensis*, *adonaensis*, *jessica*, and *enodis*. A *Subulina* with hairy epidermis (*hirsuta*) closes the list, with one *Pupa* (*rupicola*). These twenty-two together with eleven operculated species give a total of thirty-three. It is a curious fact that there is not a single *Helix* in the collection. The freshwater shells I have not yet had time to work out. A number of small forms have been brought home on the water plants that were collected, and these I have been taking out. I find among them examples of the following genera and species:—

Planorbis, no less than three species, one large.

Bithinea, one very small form.

Melania, four or five; one very beautiful spined species, reminding one of a similar form from Ceylon. One *Cerithium* occurred with these.

I have alluded to how little is known of the mainland of Africa, near Cape Guardafui. When this has been examined, and it is very necessary it should be, we shall know more as regards the range of some of these Socotran forms; and I hope that the British Association will be able to assist a naturalist to visit this district.

Report of the Committee, consisting of Mr. SCLATER, Mr. HOWARD SAUNDERS, and Mr. THISELTON DYER, *appointed for the purpose of investigating the Natural History of Timor-laut.*

IN a letter addressed to Sir Joseph Hooker, Director of the Royal Gardens, Kew, Mr. H. O. Forbes wrote from Sumatra, offering, if some assistance could be forwarded him, to attempt an expedition to Timor-laut for the purpose of investigating its natural history—'an object,' as Mr. Forbes states, 'the accomplishment of which is desired both by botanists and zoologists.' An application on Mr. Forbes's behalf was accordingly made to the British Association, and a sum of 50*l*. was voted by the General Committee at the Swansea Meeting to be placed at the disposal of the Committee, to whom the conduct of the matter was entrusted.

The action taken by the Association was communicated to Mr. Forbes, and the letter, of which a copy is annexed, was received in reply. This is the most recent information which the Committee possess as to his plans. It is somewhat doubtful whether, owing to insufficiency of funds, he was able to start. At any rate, the grant made at Swansea remains in the hands of your Committee.

The expedition is obviously attended with some difficulty, if not danger. Its success must be largely dependent on fortunate accident.

Your Committee, however, think that there is a reasonable chance of the work being done, and therefore recommend their reappointment, and that a further sum of 100*l.* be placed at their disposal.

S. SUMATRA,
December 8, 1880.

SIR JOSEPH HOOKER,

Dear Sir,—Accept my warmest thanks for the kind interest you have taken in my intended visit to Timor-laut, which has obtained for me a grant of 50*l.* from the Council of the British Association.

For the present I am engaged in Sumatra, but about the end of February, or beginning of March, I intend to return to Batavia, in order to make my way to Timor-laut. His Excellency the Governor-General kindly placed at my disposal such ships of the Dutch Navy as might be on the Amboina Station going down towards the Tenimber Islands. I have, however, given up the hope of being able to accomplish my object if I travel by this means, as the islanders are at best not very friendly, and by landing from a man-of-war I am not likely to meet with greater favour. I mean, therefore, to attempt the journey in one of the Arab prahus instead, which go there to purchase horses. I have been fortunate in securing the friendly assistance of the highest rank Arab in Java, a very clever influential man (the Native Master of Ceremonies to the Governor), whose brother is one of the largest traders to the Eastward Islands. He has offered to send forward intimation of my coming, and to do his best to secure, as far as he can, the goodwill towards me of the natives, with whom his countrymen deal.

Neither the time of my departure nor of my return can I positively fix ; the former date depends on the state of the monsoon, which these few years back has been very irregular, the latter on the amount of goodwill which the natives show towards me. If I find them not very ill-affected towards strangers, I may extend my stay over the dry monsoon, and do my best to hold out till the return of the trading season at the end of next wet monsoon.

If, therefore, the British Association grant be placed at my disposal, I shall draw upon it only on my actual departure for Timor-laut. Notwithstanding the very bad character given to the Tenimber Islanders by the Dutch officials, I have good reason to think that the perils are much exaggerated; and I hope for the best.

Again offering you, and those who so kindly supported the application made on behalf of the exploration of Timor-laut, my best thanks,

Believe me, yours obediently,
(Signed) H. O. FORBES.

Report on the Marine Fauna of the Southern Coast of Devon and Cornwall, by SPENCE BATE, *F.R.S., and* J. BROOKING ROWE, *F.L.S.*

IN presenting our report on the exploration of the marine fauna of the south-western coast of England, we beg to state that we have carried on a series of dredgings off the coast between Plymouth and Falmouth, more especially off the district known as the Dudman.

Here, in from forty to sixty fathoms, we have invariably met with some of our most interesting forms, such as are considered of the rarer species belonging to our British fauna.

Hitherto among crustacea we have taken species of Nika, Typton, Nephropsis, Caridina, Callianassa, and other forms that have generally been considered as very rare, and this year we have taken, at a depth of fifty-five fathoms, a considerable number of *Pagurus sculptimanus* of Lucas, a species that the late Prof. Bell has described in his 'History of British Stalk-eyed Crustacea,' under the name of *Pagurus forbesii*, under the impression that it was an undescribed form—a single specimen of which was sent to him with others from the coast of Falmouth.

This is the first time that this species has been taken in British waters since Bell received his specimen, which is now in the British Museum (whither we propose sending some of the recently dredged specimens), from the late Dr. Cocks, some thirty-five or forty years since; a fact that appears to suggest that the word 'rare,' as used in relation to our knowledge of species, merely represents our want of knowledge of the natural habitat of the animal.

An example of this may be seen in the following passage from Professor Bell's work on *Polybius henslowii*, 'which is very local in its distribution, and probably nowhere existing in great numbers'; whereas I have recently been informed by Mr. F. Day, that it has been thrown up on the shores of Mount's Bay, this spring, after a strong south-western gale, in such quantities that it is thought that along the shore there could not have been less that two tons in weight.

Again, the little crustacean which Bell has described as *Thysanopoda couchii*, and of which he states, on the authority of Couch, that it is found in 'myriads in the stomach of the mackerel and other fish,' Mr. Couch had not found since, although he was in the habit of searching the stomachs of mackerel and other fishes. Our experience is confirmatory of that of Mr. Couch, inasmuch as we have only obtained it one season, and then in abundance from the stomachs of fish. And recently we have had our attention drawn to a parallel fact in the Indian seas, from whence Professor Milne-Edwards described, under the name of *Acetes indicus*, in 1829, a small crustacean, that, as far as we are aware, has not been noticed since; yet Sir Walter Elliot has given us a carefully drawn figure of the same, with the remark that it was found in the stomach of a very large *Dicerobetes*, taken off the coast of Malabar in such quantities that basketfuls were carried away by the fishermen, and thousands left scattered about the shore.

In referring still to the crustacea we beg to draw attention to the fact that many of the specimens recorded from this locality—that is, from the deeper water at the entrance of the English Channel—are species that are common to the Mediterranean Sea, while others, such as *Munida bamficus*, as also others of less noticeable forms, have their centre of radiation near the arctic zones.

Although it has been several times demonstrated that deep-sea species have a large geograpical distribution, yet it is interesting to observe that some of our long-shore species have been represented by specimens that appear to be identical in the eastern seas. Thus the common *Crangon vulgaris* has its representative at Japan, or one that cannot, on the closest analysis, be distinguished from it. This is also found to be the case with one of our specimens of *Caprella* (*Caprella equilibra*) as well as other species.

We are therefore much inclined to believe that by a series of deep-water explorations—by which we mean the dredge and deep-water tow-nets, situated so as to sweep the sea at each successive fifty fathoms of water —very interesting and valuable results would be obtained. It is our strong conviction that many of the specimens recorded from very great depths are inhabitants of mid-water rather than dwellers at the sea-bottom, from whence they are supposed to have been brought.

Hitherto we have had at our command only fishermen's trawlers and shore-boats; but to explore the deep water that surrounds the south-western limits of Cornwall and the Scilly Islands would require vessels of larger tonnage and greater power than we have been able to procure with the grant placed at our disposal.

Among the fish and other animals, numerous specimens of various species have been procured. Those that are the most seldom met with on our coast have been preserved; and here we would like to record that specimens of fish and crustacea which have been preserved, as recommended by us at the meeting of the British Association at Brighton, and have been so kept for several years, are soft and flexible, and retain much of the colours of living specimens.

Numerous annelids and zoophytes have also been obtained, but we have not to record any that appear to be new or differ from those that have been reported by us in the lists already published.

As soon as our specimens are all arranged and tabulated, we hope to forward some to the British Museum, and present the rest to the Museum of the Plymouth Institution.

Report of the Committee, consisting of Professor A. C. RAMSAY *and* Professor JOHN MILNE (*Secretary*), *appointed for the purpose of investigating the Earthquake Phenomena of Japan.*

THE Seismological work which I have been engaged upon since the British Association generously placed the grant of 25*l*. in the hands of Andrew Ramsay, Esq., and myself as an assistance towards the investigation of the earthquake phenomena of Japan, has been partly a continuance of experiments and observations commenced four years ago, and partly the commencement of experiments more or less new.

The results of work which has been accomplished has been almost wholly read before the Seismological Society of Japan, and will very shortly appear in its Transactions.

The work which I have been engaged upon since receiving the grant has been as follows:—

I. *Attempts to determine the area from which the shakings so often felt in Tokio and Yokohama emanate.*

To do this, instruments intended to record the direction and maximum amplitude of an earthquake were placed at four points, from 10 to 20 miles apart, round the upper portions of Yedo Bay. For the shakings of January 7, 22, and 24 of this year, lines drawn parallel to the direction of motion at these different stations intersect each other in a number of points between Yokohama and Kanasawa.

Although several other earthquakes have had their origin localised in the same district, there remain several, the origin of which has not been localised, the records of direction being probably in many cases, and certainly in some, a confusion of normal and transverse vibrations.

As a confirmation of these results, I find by a careful series of time observations made by myself in Tokio and in Yokohama, by Mr. W. H. Talbot, for the accuracy of which we are indebted to the telegraph department who daily furnished us with a time-signal, that many shocks have been felt about 30 seconds in the latter place before they were felt in the former.

The facts that in Yokohama small earthquakes are sometimes felt which are not recorded in Tokio, and also that at the time of a severe shock the vertical motion appears to be greater in Yokohama than in Tokio, may also be taken as indications that the origin of many of the recent earthquakes has been nearer to Yokohama than to Tokio.

In order to make the localisation of the various shocks more certain, I have very recently established instruments in Tokio and Yokohama which give graphical records of both the normal and transverse vibrations. When similar instruments have been established at the remaining stations, the complete distinction between these two sets of vibrations may, independently of the interest that these records have of themselves, assist us to determine the origin of nearly all the earthquakes we feel.

The district where several shocks have had their origin already localised is one showing numerous faults, and one which shows exceedingly clear evidence of recent elevations. As it is very possible that this district may still be rising, one probable inference we might make is that faults are still being formed, and are due to the elevations, and that the earthquakes are to us the announcement of the formation of these fractures.

As confirmatory of this idea we may say that, first, the records of earthquakes, as written by our seismographs, usually commence gently, then have several maxima and minima, and finally die out as they commenced; and secondly, the testimony of our feelings leads us to believe that there is a sliding, jolting kind of motion, as might be produced by one mass of rock slipping over another.

Further, I may remark that recently, since having more perfect instruments which record each successive vibration of the earth, both in regard to time and space, I have recorded shocks in Tokio with a motion almost entirely east and west, whilst the time observations showed that they must have come from the south, which is the faulted district.

Assuming that these records are correct, and I have no reason to believe that they are not so, it would seem that from the faulted district in the south it is possible to receive an earthquake consisting only of transverse vibrations.

Such an earthquake we can imagine might be produced by a fault giving rise to an elastic wave of distortion.

If the earthquakes were produced by a blow we should have a wave of compression with normal vibrations, followed by a wave of distortion, with transverse vibrations.

Observations bearing on these points I hope to carry out during the coming year.

II. *Observations to determine the nature of Earthquake-motion.*

With the help of specially contrived seismographs, so far as my observations have hitherto gone, it is shown—1st. That the actual horizontal motion of an earth-particle at the time of an earthquake is very much smaller than we anticipated from our senses, being seldom over a few millimètres and often under one millimètre.

2ndly. The backward and forward motion of the ground is very irregular, both in regard to space and time.

3rdly. That there are seldom more than two or three complete vibrations per second.

These observations, I am pleased to say, have been confirmed by a more complete series of records than my own, obtained by Professor Ewing.

4thly. A motion often takes place in more than one direction. Both at the Yokohama station and the Tokio station records have been obtained of two sets of irregular ellipses crossing each other nearly at right angles, these ellipses being drawn by the pointer of a seismograph moving over a smoked glass plate at rest beneath it.

For the same earthquake this difference in direction may be experienced at one station, but not at another, 15 or 20 miles distant.

From records obtained it would seem possible that at Yokohama both transverse and normal vibrations may be recorded, whilst at Tokio, sixteen miles distant, only the former are recorded. As these latter observations need confirmation, I hope during the coming year to be able, with the help of a few similar instruments placed at different stations, to obtain records of a series of shakings, to show the relation between the dying out of one set of vibrations as compared with the dying out of another.

III. *The recording of Earth-tremors.*

With the help of a specially-contrived instrument, by which a motion of the earth equal to the $\frac{1}{1000}$th of an inch can be definitely recorded, I am able to say that in Tokio there are very many small disturbances in the ground, which are not registered with any of our ordinary seismographs.

My object in recording these small motions is to see, first, whether they are in any way connected with the larger motions which we call earthquakes, just as the crackling of a stick is connected with its breaking; and, second, whether there is any periodicity connected with these small movements, it being possible, for example, that influences which produce the tides in the ocean may perhaps be sufficient to produce earth *crackles*, whilst they may not (excepting where they are, so to speak, like the last straw upon a camel's back) produce an earthquake.

As Yokohama appears to be nearer to the origin of many of our earthquakes than Tokio, and also because, as compared with Tokio, it stands upon the rock, I have quite recently taken two of my tremor instruments there. One of them has been placed in the hands of Mr. W. H. Talbot, and the other with Mr. H. Pryer, these gentlemen having very kindly undertaken to keep a record of their movements.

IV. *An endeavour to find out the relative extent of motions and variation in direction of an earthquake in passing over a limited area, the contour and geological structure of which is irregular.*

To work out this problem I have distributed six similar seismometers on the hills and in the valleys near my house. Since being established only four earthquakes have been recorded. Until a number of shocks have been felt I can hardly speak of what the result of this investigation may be.

V. *The carrying out of a long series of experiments on artificial earthquakes in the alluvium of the Tokio plane.*

These experiments were carried out jointly with my colleague Mr. Thomas Gray.

These earthquakes were produced by allowing a heavy iron ball to fall from various heights up to 35 feet. The results obtained were as follows:—

1. A partial determination of the effects of cuttings (like a deep pond) and hills upon the transmission of vibrations. Small hills seemed to produce but little effect in stopping transverse vibrations, but a pond to a certain extent cut off both transverse and normal vibrations.

2. A complete graphical separation of normal from transverse vibrations.

3. A determination of the relative amplitudes of normal and transverse vibrations as observed at points differently situated with regard to the origin of the shock. It appeared that although near to the origin the amplitude of the normal vibrations was greater than that of the transverse ones; as we made observations at more distant stations these normal motions diminished more rapidly than the latter. Roughly speaking, the amplitude of the normal vibrations was inversely as the distance from the origin of the shock. The transverse vibrations diminished in amplitude more slowly.

4. There appeared to be usually about *six* vibrations per second. The normal vibrations were the more rapid.

5. The average velocity of the normal vibrations was 438 feet per second, whilst that of the transversal movements was only 357 feet.

6. At a distant station (250 feet) four or five dissimilar vibrations would be first recorded, and then the same four or five vibrations would be repeated in the same order as first recorded. At times this cyclic-like action was very distinct.

7. The experimental determination (by bending and twisting) of the elastic moduli, &c., of several common Japanese rocks. These experiments were performed in conjunction with my colleague, Mr. Thomas Gray, in the physical laboratory of the Imperial College of Engineering.

In addition to the work which I have mentioned as being before me for the coming seismic season, I shall endeavour to increase the stations where time-observations have been made from two to three or four, at all of which telegraphic signals can be received. I do this, firstly, because I find from experience the important part taken by time-observations in the interpretation of the best of our records; and, secondly, because they may perhaps be the means of showing us the true relations existing between normal and transversal movements.

In conclusion I must remark that had I not, previously to the time at which I received the grant of the British Association, been engaged in recording earthquakes, and spent much time in experimenting with various instruments, testing each with a long series of actual earthquakes (*see* 'Transactions of the Seismological Society of Japan'), I should not have been in the position to carry out the work which has here been referred to.

As I have established a small earthquake observatory, and have by several years' experience determined upon instruments which appear to me to be best suited for some of the more important seismological investigations, have obtained and taught observers at various stations, and, lastly, have received the co-operation of several friends—one of whom, Mr. W. H. Talbot, has also established a special observatory—I sincerely hope that the British Association will see fit to extend its previous grant for the working out of seismic problems in a district which, amongst all others, is one of the very best for carrying on such observations.

Ninth Report of the Committee, consisting of Professor PRESTWICH, Professor T. McK. HUGHES, Professor W. BOYD DAWKINS, Professor T. G. BONNEY, Rev. H. W. CROSSKEY, Dr. DEANE, *and* Messrs. C. E. DE RANCE, D. MACKINTOSH, R. H. TIDDEMAN, J. E. LEE, J. PLANT, W. PENGELLY, W. MOLYNEUX, H. G. FORDHAM, *and* W. TERRILL, *appointed for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation. Drawn up by the* Rev. H. W. CROSSKEY, *Secretary.*

DURING the past year this Committee has pursued the researches entrusted to it; and is able to record the following additional instances of the occurrence of Erratic Blocks.

Cumberland.—Mr. T. A. Colfox furnishes the Committee with the following particulars respecting granite and sandstone boulders found while excavating for the new docks at Maryport, parish of Dearham, Cumberland.

The granite boulders vary in size from small pebbles to a ton or thereabouts in weight.

Those of the New Red Sandstone, which occur at a lower level, vary from half a ton to two tons or more.

The granite boulders are rounded; those from the New Red Sandstone have sharp angles. No ruts, groovings, or other marks are visible.

The nearest granite occurs in the Kirkcudbrightshire hills on the other side of the Solway, 15 or 20 miles distant, nearly due north; the New Red Sandstone is the stone of the district.

The granite specimens are numerous, but only four or five of the New Red Sandstone ones have been found. The former were resting on the top of a bed of sandy clay, underlying the sand and shingle of the foreshore, at a depth of 10 to 15 feet below the surface; the latter occur in the bed of clay itself, 15 or 16 feet above the New Red Sandstone rock, similar to the boulders themselves, which underlies the clay.

The height of the group of granite boulders was 2 feet or 3 feet *below low water* at ordinary spring tides.

About three acres have been at present excavated.

Yorkshire.—In previous reports a description has been given of Shap Granite Boulders, found in the neighbourhood of Filey.

One of these Shap Granite Boulders has now been removed to the University Museum, Oxford, and placed, with a descriptive inscription, on the lawn in front.

It was found near the edge of the cliff about half a mile N. of the old church, Filey, Yorkshire.

It measures 3 ft. 1 in. × 3 ft. 7 in. × 1 ft. 9 in., and is subangular or rounded.

It has apparently been moved, although nothing is known respecting this point.

Shap, near Penrith, the nearest place where a red porphyritic granite of the same character is found, is 108 miles distant, bearing W.N.W. from Filey.

The boulder described rested on Oolitic strata, at a height of about 150 feet above the sea.

Anglesea.—Professor T. McK. Hughes draws the attention of the Committee to a boulder which occurs near the centre of Anglesea. It is chiefly interesting as having been by some considered an inscribed stone; but the supposed characters are entirely due to rock-structure.

It consists of bands of porphyritic hornblende diabase, occurring along master joints in ordinary hornblende diabase; with cross joints terminated at the master joints, and having the appearance of runic characters. It measures 7 ft. × 5 ft. 4 in. × 4 ft. 3 in. It occurs in a field on E. of the railway opposite Cae Scynan, about $\frac{3}{4}$ mile S. of Llanerchymedd, Anglesea, and may have been derived from a dyke near Gorphwysfa, about 7 miles distant.

Attention has already been called to this boulder by the Rev. W. Wynn Williams in the 'Archæologia Cambrensis.'

Leicestershire.—Mr. J. Plant continues, as follows, his reports to the Committee on the erratic blocks of this county.

In the parish of Knighton, on the Clarendon Park Estate, Leicester, are two boulders, the longest 5 ft. × $4\frac{1}{2}$ ft. × 3 ft. 9 in.; the smallest 4 ft. × 3 ft. 1 in. × 2 ft. 3 in. They are subangular and not known to have been moved. They are derived from Mount Sorrel, W. of N. a few degrees, 7 miles distant. The two blocks are of granite, and lie close together at a height of 300 feet above the sea-level, and were found under 8 feet of mottled drift clay in digging out foundations of houses.

In the parish of Stoughton, on the 'Dairy Farm,' near Leicester, are two blocks of granite, the longest being 4 ft. × 3 ft. × $2\frac{1}{2}$ ft. They are subangular and not known to have been moved by man, and are derived from Mount Sorrel, 9 miles N.W. They lie together on the surface, 360 feet above the sea-level.

In the parish of Evington, on the Lodge Farm, Leicester, are three blocks of granite, the longest $4\frac{1}{2}$ ft. × $2\frac{1}{2}$ ft. × 1 ft; the smallest, 3 ft. × $2\frac{1}{2}$ ft. × 1 ft.; they are subangular, and have been derived from Mount Sorrel, 7 miles N.W. The three blocks lie close together on the surface, 360 feet above the sea-level.

In the parish of Aylestone, Leicester, is a group of syenite boulders; the longest is 4 ft. × 3 ft. × $1\frac{1}{2}$ ft., and is rounded. It was derived from Groby, 5 miles N.W., and lies exposed on the surface, 190 feet above the sea-level.

A number of boulders in this locality have been described in my previous report, which are far below the height at which they must have been originally deposited. They are now found lying in the alluvium of the valley of the river Soar, having subsided to their present position as the *débris* was washed away by floods from age to age.

On the estate of Spinney Hills, at Lodge Farm, Leicester, is a group of boulders of millstone grit and granite, the longest 3 ft. × 2 ft. 6 in. × 1 ft. 9 in.; the smallest, 2 ft. × 1 ft. × 1 ft. The largest block (millstone grit) is very much rounded, the others (granite) are subangular and angular. There are faint striæ on the millstone grit. The millstone grit may be derived from Stanton, near Melbourne, Derbyshire; the granites from Mount Sorrel. The former is about 35 miles N.W.; the latter 6 miles N.W. The granite blocks are the most numerous. They are 320 feet above the sea-level.

These boulders were in a deposit of stiff tenacious clay drift, 8 feet deep, and were found lying upon the denuded surface of the rhætic beds, which were uncovered in making a new road. The boulders are found on the S.E. face of the hill, although they have travelled from the N.W.

In the parish of St. Margaret's, on the estate of Abbey Meadow, Leicester, are three blocks of granite, the longest being 2 ft. × 2 ft. × 1 ft.; the smallest, $1\frac{1}{2}$ ft. × 1 ft. × 1 ft. They are rounded and subangular, and were derived from Mount Sorrel, 6 miles N. They were exposed in excavating a new river-bed, and were found lying under 8 feet of coarse pebbly drift (which forms an extensive deposit all over this area), at a height of 165 feet above the sea-level.

In the parish of Rothley, on the estate of Rothley Temple, Leicester, is a group of four granite boulders, the longest 3 ft. × 2 ft. 6 in. × 2 ft.; the smallest, 2 ft. 6 in. × 2 ft. × 2 ft. They are subangular, and were derived from Mount Sorrel, 2 miles due north. They lie exposed on the surface, 280 feet above the sea-level.

In the parish of St. Margaret's, on the Great Northern new line of railway, Willowbrook, Leicester, are four boulders, the longest 3 ft. × 2 ft. × 2 ft.; the smallest 2 ft. × 2 ft. × 1 ft. 3 in. The millstone-grit blocks are rounded; the altered slate are angular, the granites sub-angular.

The millstone grit may be derived from Stanton, Derbyshire; the altered slate from Swithland; the granite fron Mount Sorrel. Stanton is 35 miles N.W.; Swithland 5 miles N.W.; Mount Sorrel 6 miles N.

These boulders were uncovered in excavations for the line of railway, and were found at various depths in a drift composed almost entirely of rounded pebbles, 175 feet above the sea-level. Numerous other erratics, but of smaller dimensions, are found scattered throughout the mass. The depth exposed at various points of this coarse pebbly drift varies from 10 to 20 feet, but as the solid rock was in no case reached, it must be much deeper. This deposit must be of immense extent, it having been found at various points over an area of 2 miles by $1\frac{1}{2}$ miles. The pebbles constituting this pebbly drift are very much rounded and polished.

In the parish of St. Mary's, on the Victoria Park estate, Leicester, is a widely extended group of boulders; the longest $1\frac{1}{2}$ ft. × 1 ft. × 1 ft.; the smallest cube of about 10 inches. Many of them are rounded, sub-angular, and angular. They were derived from localities all round this county except the south side, extending from 6 to 60 miles, and from all points of the compass except from the south.

They comprise granites, syenites, slates, grits, sandstones, mountain limestones, oolitic limestones, lias limestones, marl-stones, chalk-flints, coal and coal-shales, &c.

The group is 290 feet above the sea-level and covers about 100 acres; the number counted was 500. They were turned out in an extensive system of draining carried out over the whole area to a depth of 4½ to 7 feet, in widths varying from 1½ to 2 feet. All occur in drift, gravel, sand, and clay. Many thousands of erratics must lie concealed under the remainder of the area.

The great 'Erratic,' called the 'Holy stone,' at Humberstone (briefly alluded to in the Second Report for 1874, and more fully described in the Sixth Report for 1878), one of the largest yet discovered in the midland counties, is now entirely uncovered, and some fine photographs (on a large scale) have been taken of it. The block is pentagonal in shape, the sides are quite vertical, and are of the following dimensions in length, 7 ft., 6 ft. 4 in., 5 ft., 5 ft. and 4 ft. 4 in. It may be observed that two of the sides of 5 feet each are opposite to each other. The depth of the sides is 5 feet. The longest axis is 10 feet, and the next in length (and at right angles to it) is 9 feet.

The vertical sides and corners of the block are as fresh as if recently quarried, and no groovings can be seen upon them. The upper surface (the longer axis of which lies N. and S.) has several deep irregular grooves running N. and S., but these are considered to have been done since the block was deposited, as it is thought, from reasons that cannot be here entered upon, that it has been *very much higher*, and that a considerable portion of the upper part has been worn away by natural and artificial causes.

The bottom of the block cannot be seen without turning it over, and this would be a work of some labour. Careful calculation makes the weight nearly 21 tons.

The block rests on a denuded bed of the rhætic formation, and the material around it, which nearly covered it, is of recent accumulation, so that originally it is thought to have stood quite exposed. The height of the hill from which it is considered to have been brought is about 400 feet above the level of the sea, and is situated 6 miles N.W. The hill-side on which the block now rests is about 240 feet above the sea, and there is a river valley between these two points (at *right angles to the line of transit* of the block) which is only 110 feet above the level of the sea.

The proprietor, in obliging compliance with the request of the Committee, will take measures for its preservation.

Hertfordshire.—Mr. H. George Fordham, F.G.S., presents the following report on the Erratic Blocks of the parish of Ashwell.

[Ordnance Maps—1-inch, Sheet 46. N.E., and 25-inch, Parish Map.]

The village of Ashwell lies in the middle of the parish, on the Chalk Marl and the lowest beds of the Lower Chalk, at the foot of a ridge of Lower Chalk hills, from which the river Cam, or Rhee, rises on the east side of the village.

To the north the parish is flat, consisting of Chalk Marl, through which the river cuts a narrow channel, and it just reaches the Gault in its extreme northern point, about 2¾ miles from the village.

The village itself is about 160 ft. above sea-level (Bench-mark on church = 162·5 ft.).

South and south-east of the village the ground rises rapidly into the ridge above referred to—highest point, about half-a-mile from the village (Clay Bush Hill), 329 ft.—and this ridge runs S.E., at right angles to the main line of hills formed by the upper beds of the Chalk, constituting the edge of the London basin, until it joins this high ground near Kelshall.

The ridge near Ashwell bends away towards the north-west, and gradually loses its elevation. It forms the line of division between the valley of the Cam, or Rhee, and that of the Ivel, which latter stream flows into the Ouse.

There do not appear to be any boulders on the flat ground north of the village, nor on the low hills in other parts of the parish, and the only locality for boulders within the parish seems to be the upper part of the ridge of high ground already described. The whole of the higher part of this ridge, within the parish, is covered with clays and gravels of glacial origin; and it is clear from the uneven appearance of the surface, that the ground during long periods has been worked to obtain materials for road-making and other purposes; and to a small extent it is still so worked. From this source, we may fairly assume, has been derived the large quantity of pebbles and boulders which we now find in all parts of the village of Ashwell. Indeed, at the present day, boulders are brought down from time to time from the one gravel-pit now open.

The boulders and pebbles, of which the following is a catalogue, and which are found in different parts of the village, must be therefore considered as belonging to the ridge *above the village*, from which there is every reason to suppose they have all, at one time or another, been obtained, from a height of from 270 ft. to 329 ft. above the sea.

The catalogue includes all the larger blocks, and such smaller ones as appear to be representative in point of material, or of any interest from external characteristics.

The measurements and descriptions of external appearances are from my own observations; for descriptions of the rocks I am indebted to Professor Bonney, to whom specimens have been submitted. He writes that, as they reached him when away for some time from books and collections, he has not attempted to name the few and generally imperfectly preserved or exposed fossils which he has noticed.

Boulders lying at the end of barrel-washing shed, Ashwell Brewery.

1. Roughly cubical, angles but little worn, surfaces nearly flat and somewhat smoothed. Fine sandstone: may be either carboniferous or jurassic. $15\frac{1}{2}$ in. × 12 in. × $11\frac{1}{2}$ in.

2. Irregular shape, much rounded and smoothed on two sides (probably by man). Fine sandstone: carboniferous or jurassic. 15 in. × $10\frac{1}{2}$ in. × 8 in.

3. Rounded fragment, breaking into slabs along planes of bedding. Ferruginous calcareous sandstone: neocomian, or possibly carboniferous. 10 in. in longest diameter.

4. Irregular shape, smoothed and worn. Fine sandstone: neocomian, or possibly carboniferous. 12 in. × 9 in. × 5 in.

5. Irregular, slightly smoothed. Fine, hard sandstone: possibly inferior oolite, if not, probably carboniferous. 11 in. × 7 in. × 6 in.

6. One side flat, the other sides irregular and smoothed. Hard sandstone: possibly oolitic. 11 in. × 10 in. × 10 in.

7. Very irregular in shape, smoothed, rounded, and marked with lines of bedding. Ferruginous sandstone: oolite, or neocomian. 17 in. × 13½ in. × 8 in.

8. Rounded and smoothed. Ferruginous sandstone: oolite or carboniferous. 8 in. × 6 in. × 4 in.

9. Somewhat wedge-shaped, with two of its faces flat. Generally smoothed and worn. Compact limestone: probably carboniferous. 9½ in. × 9 in. × 5½ in.

10. Roughly prismatic, irregular surface, slightly worn. Fine, ferruginous sandstone: inferior oolite or neocomian. 12 in. × 7 in. × 6 in.

11. Somewhat broadly wedge-shaped, with several perfectly flat and smoothed plane surfaces. Basalt. 10 in. × 9 in. × 6 in.

12. Irregular and smoothed. Fine, hard, rather ferruginous sandstone: possibly inferior oolite. 12 in. × 8 in. × 4½ in.

13. Broken end of boulder, rounded, one surface nearly flat. Sandstone: carboniferous or jurassic. 6 in. × 6 in. × 4½ in.

14. Oval, smoothed and worn, all the angles worn off and most of the faces smoothed and flat. Evidently much rolled and worn. Traces of parallel grooving on one face: compact sandstone. 15 in. × 12 in. × 8 in.

15. Long-shaped, rounded and worn, with one long flat face, ? scratched: compact sandstone. 18 in. × 11 in. × 7½ in.

16. Roughly prismatic, irregular surfaces, rounded. Ferruginous sandstone: oolitic or neocomian. 15 in. × 10 in. × 8 in.

17. Prismatic, angles rounded. Somewhat pyramidal in shape. 13½ in. × 12 in. × 6½ in.

Boulder at corner of stable, Ashwell Brewery Yard.

18. Rounded, much worn by atmospheric action and ill-usage, and the surface consequently rough and broken. Coarse sandstone, rounded, glazed grains: neocomian. 16 in. × 12 in. × 9 in.

Boulders in pavement near wall of garden, Ashwell Brewery Yard.

19. Small boulder. Basalt, rather decomposed. 7 in. × 7 in. × ?.

20. Pebble, oval and worn. Ferruginous sandstone: probably neocomian. 6 in. × 2½ in × ?.

Boulders bedded in the ground along side of garden wall, Ashwell Brewery Yard.

21. Oval, worn. Fine, hard sandstone: carboniferous or oolite. 11 in. × 6 in. × ?.

22. Roughly rectangular, with uneven, smoothed upper surface. Sandstone with carbonaceous markings. 11 in. × 7½ in. × ?.

23. Apparently a fragment of larger boulder, with flat surface of fracture. Other sides smoothed and rounded. Compact limestone: carboniferous or oolitic. 13 in. × 7 in. × 6½ in.

24. Smoothed and rounded. Compact limestone: mountain limestone (?). 10 in. × 6½ in. × ?.

25. Smoothed, uneven upper surface, nearly flat. Angles but little worn. Basalt. 9 in. × 6½ in. × ?.

26. Roughly rectangular, smoothed, angles little rounded. Basalt. $7\frac{1}{2}$ in. × 7 in. × ?.

27. Long-shaped, pointed at one end, worn, but without any definite plane surfaces. Several rounded knobs on different parts of the surface. Basalt. 11 in. × 7 in. × 6 in.

28. Worn, cuboidal. Ferruginous sandstone. 10 in. × 7 in. × ?.

29. Cubical, slightly worn angles, and surfaces nearly flat and smooth. Coarsish ferruginous sandstone. 8 in. × 7 in. × ?.

30. Very uneven surfaces, covered with little knobs and depressions, broken on one side. Crystalline; a coarse gneiss with black mica. $8\frac{1}{2}$ in. × 7 in. × $5\frac{1}{2}$ in.

31. Smoothed and much worn, marked in some parts by irregular, broad grooves. Hard sandstone: possibly oolitic. 12 in. × 7 in. × 7 in.

32. Flat, smooth upper surface, angles but little worn. Hard sandstone: carboniferous or oolite. $10\frac{1}{2}$ in. × 6 in. × ?.

33. Rounded and smoothed. A crystalline rock, not in very good condition for examination: contains felspar crystals:— ? a porphyritic gneiss. 7 in. × 5 in. × ?.

Boulders forming edge of path, outside end of garden, entrance to Ashwell Brewery Yard.

34. Cubical, smoothed, angles slightly rounded, and sides nearly flat. Fine sandstone: carboniferous or oolite. 13 in. × 14 in. × ?. (Noted in Fifth Report of the Committee.)

35. Subangular, surfaces smoothed. Ferruginous sandstone: neocomian or oolite. 7 in. × $5\frac{1}{2}$ in. × ?.

36. Rounded, worn. Calcareous, ferruginous sandstone: probably oolite. 8 in. × 7 in. × ?.

37. Rounded, flattish, worn. Ferruginous sandstone: neocomian or oolite. $7\frac{1}{2}$ in. × $7\frac{1}{2}$ in. × 5 in.

38. Flattish, smooth, rectangular, angles worn. Hard sandstone: carboniferous or oolite. $10\frac{1}{2}$ in. × $8\frac{1}{2}$ in. × 6 in.

39. Nearly spherical, worn; surface slightly uneven, but well rounded as a whole. Hard, ferruginous sandstone: probably oolitic. $10\frac{1}{2}$ in. × 9 in. × ?.

40. Upper surface flat, otherwise rounded. Coarse sandstone: rather like a millstone grit. $11\frac{1}{2}$ in. × 11 in. × ?.

41. Rounded, somewhat rectangular pebble, well-worn. Ferruginous sandstone: probably neocomian. 6 in. × 4 in. × ?.

42. Rounded, with several flat surfaces. Ferruginous sandstone; well-rounded grains: probably neocomian. 13 in. × $8\frac{1}{2}$ in × ?.

43. Subtriangular, rounded and smoothed. Hard sandstone: carboniferous or oolite. 10 in. × $7\frac{1}{2}$ in. × ?.

44. Rectangular, with rounded angles and smoothed surfaces. Sandstone: neocomian or oolite. 13 in. × 7 in. × ?.

45. Oval, rounded and worn. Sandstone: probably oolitic. 16 in. × 9 in. × ?.

46. Somewhat rectangular, angles rounded, sides nearly flat. Sandstone: carboniferous or oolite. 13 in. × 7 in. × ?.

47. Long, subangular, stratified slab. Ferruginous sandstone: probably oolite. 19 in. × $5\frac{1}{2}$ in. × ?.

48. Rectangular, sides flat, angles but little worn. Fine, ferruginous sandstone: probably neocomian. 12 in. × 5 in. × ?.

49. Rectangular, but much worn, and angles rounded. Ferruginous sandstone: neocomian or oolite. 9 in. × 5 in. × ?.

50. Rounded. Ferruginous sandstone: neocomian or oolite. 7 in. × 5 in. × ?.

51. Broken slab, with sharp angles round one face, but otherwise much worn and smoothed. Basalt. 18 in. × 5 in. × ?.

52. Flattish, smoothed, worn, surface irregular. Sandstone: probably jurassic. 8 in. × 9 in. × 5 in.

53. Roughly prismatic, with angles rounded and faces smoothed. Sandstone, with annelid markings. 9 in. × 6 in. × 6 in.

54. Subangular, prismatic slab, angles rounded and whole surface smoothed. Hard, ferruginous sandstone: carboniferous or oolite. 15 in. × 6 in. × ?.

55. Rounded, smoothed. Ferruginous sandstone: probably oolitic. 9 in. × 6 in. × ?.

56. Rounded and smoothed. Sandstone: probably neocomian. 8 in. × 7 in. × $4\frac{1}{2}$ in.

57. Subangular, worn. Ferruginous, calcareous sandstone: neocomian or oolite. 11 in. × 6 in. × ?.

58. Broken fragment, rounded and worn. Compact limestone: probably carboniferous limestone. $5\frac{1}{2}$ in. × 6 in. × ?.

59. Subangular, irregular, little worn. Pink-red, mottled, ferruginous sandstone: neocomian or oolite. 6 in. × 7 in. × 4 in.

60. Piece of somewhat worn chalk-marl [doubtfully a boulder.] 17 in. × 9 in. × 6 in.

Slab in pavement in front of boiler-room door, Ashwell Brewery.

61. Upper surface smooth and flat, angles rounded. Compact sandstone. 21 in. × 16 in. × ?.

Boulder lying at end of barn opposite office, Ashwell Brewery.

62. One end broken, otherwise much rounded and smoothed. Coarse sandstone or grit. 15 in. × 11 in. × 6 in.

Boulder lying on S. side of entrance to Ashwell Brewery Yard.

63. Irregularly-shaped, faces flat and smoothed, angles but little worn. Hard, compact sandstone. 18 in. × 12 in. × ?.

Boulder on N. side of entrance to Ashwell Brewery Yard, against corner of house. [Since moved into stable yard adjoining.]

(This is the large boulder referred to in the Fifth Report:—the measurements are now taken somewhat differently.)

64. Rounded and much worn, without any particular regularity of shape. When moved the lower portion of the surface, where it had not been exposed, was much less worn, and rather uneven. Sandstone: corresponds in character with hand-specimens of mill-stone grit. 2 ft. 10 in. × 2 ft. 8 in. × 2 ft. 0 in.

Boulders from large heap of pebbles at end of stable, Ashwell Brewery Yard.

65. Irregularly prismatic, angular, angles slightly worn. White quartzite, probably derived from pebbles in Bunter. [It is somewhat doubtful whether this is a boulder; possibly it has been brought here with building materials, or in some similar way.] 12 in. × 7 in. × 4½ in.

66. Broken, rounded pebble. Appears to be a dark felsite or porphyrite: possibly from the Cheviots. 4 in. × 4 in. × 3 in.

67. Rounded pebble. Basalt. 6 in. × 4 in. × 3 in.

Boulder at corner of house at angle of road to The Bury, in Mill Lane.

68. Worn and smoothed slab, showing lines of bedding, and weathering iron-red. Coarse, deep red, ferruginous sandstone, with rounded grains: neocomian. 2 ft. 0 in. × 2 ft. 0 in. × 1 ft. 0 in.

Boulders used as stepping-stones at the Springs.

69. Irregularly-shaped, angles well rounded, and sides smoothed. Top much worn by use as a stepping-stone. Hard ferruginous sandstone, weathering red. 2 ft. 4 in. × 1 ft. 10 in. × 1 ft. 5 in.

70. Irregularly-shaped, worn and smoothed. Coarse, rather ferruginous sandstone. 2 ft. 1 in. × 1 ft. 5 in. × 1 ft. 4 in.

Boulders on side of road, at the W. end of 'The Cricketers' Beerhouse.

71. Flat, roughly hexagonal slab, top quite smooth and flat, sides and angles worn. Compact, light-yellow sandstone. 2 ft. 6 in. × 1 ft. 11 in. × 1 ft. 0 in.

72. Rounded, many-sided block, surface rough and granular from exposure. Granite, with black mica, not unlike that of Criffell. 16 in. × 14 in. × ?.

Boulder at corner of 'The Waggon and Horses,' near the Spring Head.

73. Smooth, worn and rounded, shape somewhat irregular. Basalt; weathering dark blue. 21 in. × 18 in. × 12 in.

Boulder in Greater Hodwell, at corner of garden wall, opposite the Lock-up.

74. Long, flattish, worn and smoothed. Hard, fine sandstone: carboniferous or oolite. 2 ft. 6 in. × 1 ft. 6 in. × ?.

Heap of boulders forming fernery, in extreme E. corner of garden of Brewer's House, Ashwell Brewery.

75. Rounded, weather-worn, and marked irregularly by small cracks: doubtfully scratched on upper surface. Carboniferous limestone. 11 in. × 8 in. × 7 in.

76. Much rounded, nearly oval in shape. Coarse grit: probably neocomian. 8 in. × 7½ in. × 5 in.

77. Irregularly-shaped, smoothed. Fine ferruginous sandstone: carboniferous or oolite. 9 in. × 8½ in. × 5 in.

78. Apparently a broken fragment. Irregular shape, somewhat angular, worn on one face. Carboniferous limestone, containing fossils (spiriferæ). 8 in. × 7 in. × 5 in.

79. Roughly rhomboidal, worn and smoothed. Sandstone: carboniferous or oolite. 16 in. × 11½ in. × 8 in.

80. Wedge-shaped, with flat, smoothed faces, and rounded angles. Fine sandstone: probably oolitic. 8 in. × 7 in. × 5 in.

81. Prismatic in shape, angles rounded, and faces smoothed. Coarsish, loose sandstone. 13½ in. × 6 in. × 4½ in.

82. Broken end of a sandstone boulder, similar in character and material to 81. 6½ in. × 6 in. × 3 in.

83. Thick slab, one face perfectly flat and smooth, and opposite face nearly so, angles rounded. Sandstone. 15 in. × 12 in. × 5½ in.

84. Prismatic block, angles rounded, faces smoothed and worn. Sandstone. 14 in. × 7 in. × 4½ in.

85. Much worn and rounded. Slightly ferruginous sandstone: possibly carboniferous. 20 in. (?) × 16 in. × 8 in.

86. Rounded, worn. Ferruginous sandstone: probably neocomian. 12 in. (?) × 7 in. × 4 in.

87. Prismatic, flat, smoothed faces, angles little worn. Ferruginous sandstone: probably neocomian. 16 in. × 7 in. × 7 in.

88. Much worn and smoothed. Ferruginous grit: probably neocomian. 20 in. × 14 in. × 7 in.

89. Rounded, worn, pear-shaped. Limestone: probably carboniferous. 15 in. × 11½ in. × 7 in.

90. Worn, somewhat prismatic in shape, angles rounded and sides flat. Basalt. 15 in. × 10 in. × 7½ in.

91. Much rounded and smoothed, almost to the extent of being polished. Hard, white, fine-grained sandstone: probably carboniferous. 17 in. × 10 in. × 8 in.

92. Rounded and worn. Fine, compact sandstone. 9 in. × 6 in. × 4 in.

93. Broken fragment, smoothed on one face. Black limestone: carboniferous. 10½ in. × 8 in. × 5 in.

94. Rhomboidal, faces flat, angles little worn. Ferruginous sandstone: probably oolitic. 12 in. × 6 in. × 5½ in.

95. Rectangular slab, upper face flat and smoothed, lower rather rounded. Hard, rather ferruginous sandstone: probably oolitic. 12½ in. × 9 in. × 5½ in.

96. Elongated rhomb, flat, smoothed surfaces, and angles rounded. Hard sandstone: probably oolitic. 11½ in. × 6 in. × 6 in.

97. Flat-topped, somewhat angular slab. Ferruginous sandstone: possibly neocomian or oolitic. 10½ in. × 9 in. × 4 in.

98. Smoothed and rounded slab. Hard sandstone: carboniferous or oolite. 9 in. × 6½ in. × 3½ in.

99. Roughly cuboidal, surface uneven, and slightly worn. Basalt. 7 in. × 6½ in. × 6 in.

100. Rounded, slightly smoothed. Fine ferruginous sandstone: probably oolitic. 10 in. × 7½ in. × 4½ in.

101. Rounded, smoothed. Hard sandstone: probably oolitic. 8 in. × 6 in. × ?.

102. Rounded. Fine, hard sandstone: might be neocomian or portlandian. 8½ in. × 7 in. × ?.

Boulders in High Street, in front of Jessamine Farm.
At N. corner of garden, in front of house.

103. Smoothed, rounded, faces nearly flat. Basalt. 2 ft. 6 in. × 1 ft. 8 in. × 1 ft. 6 in.

At W. corner of garden.

104. Flat, roughly triangular slab, edges rounded, upper surface broken. Fossiliferous limestone: probably oolitic. 2 ft. 2 in. × 2 ft. 0 in. × 9 in.

Boulder at side of step of door of 'The Australian Cow' Beerhouse, at corner of High Street and Lime Kiln Lane.

105. Long block, irregular shape, much worn, and angles rounded. Coarse grit; probably millstone grit. 2 ft. 5 in. × 1 ft. 8 in. × 11 in.

Boulders along side of road, against wall of lime-kiln pit, at the top of Bear Lane.

106. Irregular, rounded. Ferruginous sandstone; neocomian or oolite. 19 in. × 14 in. × 12 in.

107. Rectangular, angles but little worn, sides nearly flat. Sandstone: probably oolitic. 14 in. × 12 in. × ?.

108. Rounded, flattish oval. Part of septaria; possibly from Oxford or Kimmeridge clay. 2 ft. 0 in. × 1 ft. 4 in. × ?.

109. Rounded, somewhat oval, smoothed. Fine limestone: carboniferous or neocomian. 16 in. × 13 in. × ?.

110. Rounded, smoothed, slightly cuboidal in shape, angles well-worn. Sandstone: probably millstone-grit series. 12 in. × 11 in. × ?.

111. Similar to 108. Broken and buried in the ground, but apparently about the same size.

112. Rounded, cuboidal. Sandstone: probably millstone-grit series. 12 in. × 11 in. × 10 in.

113. Rounded, flattish block. Sandstone: neocomian or oolite. 10 in. × 9 in. × 5½ in.

Heap of boulders at junction of roads opposite lime-kiln, at the top of Bear Lane.

These have all been recently brought down from the gravel-pit on the S. side of Clay Bush Hill.

The workmen state that they are all found in the *upper part* of the gravel-beds.

[114 to 122, described below, have been taken away to be built into a wall alongside of the river where it passes under the high road outside the lower end of The Bury close.]

114. Flat slab, surface well-smoothed, and angles rounded. Very hard, fine ferruginous sandstone: possibly carboniferous. 3 ft. 0 in. × 2 ft. 0 in. × 6 in.

115. Subangular, faces flat. Sandstone: possibly carboniferous. 21 in. × 12½ in. × 11 in.

116. Worn, rounded, flattish block. Sandstone: possibly oolitic. 2 ft. 1½ in. × 1 ft. 5 in. × 1 ft. 1 in.

117. Rounded, worn. Hard sandstone: possibly carboniferous. 17 in. × 14 in. × 12 in.

118. Slightly rounded, triangular block, sides flat and smooth. Sandstone, probably oolitic. 2 ft. 1 in. × 1 ft. 7 in. × 1 ft. 0 in.

119. Sub-angular, irregular shape. Fine sandstone. 12 in. × 11 in. × 10 in.

120. Sub-angular, rectangular block, with flat faces and planes of bedding parallel to plane of longest face. Basalt. 11 in. × 8½ in. × 6½ in.

121. Smoothed and rounded slab. Sandstone: neocomian or oolite. 14 in. × 9 in. × 5½ in.

122. Flat-faced, many-sided, sub-angular block. Basalt. 10 in. × 7 in. × 5 in.

123. Sub-angular, wedge-shaped. Basalt. 8½ in. × 7 in. × 5 in.

124. Broken, rounded fragment. Basalt. 5 in. × 5 in. × 3 in.

125. Rounded, many-sided block. Basalt. 8 in. × 5½ in. × 4½ in.

Boulders and pebbles forming Rockery, &c., in the Rectory Garden.

[It is doubtful whether Nos. 126 to 155 all belong to Ashwell, as some of them are said to have been brought from a brickpit at Stotfold, Bedfordshire, three miles S.W. It is not, however, clear which, or how many, belong to Stotfold.]

126. Roughly triangular, worn. Fine, hard sandstone, probably carboniferous. 15 in. × 12 in. × ?.

127. Rough block, with surface much broken, but in some parts smoothed, and general outline rounded. Possibly a piece of septarian concretion from Oxford or Kimmeridge clay. 15 in. × 12 in. × ?.

128. Flat, triangular pebble, angles worn. Fossiliferous, impure limestone: very like Lias marlstone. 10 in. × 7 in. × 4 in.

129. Flattish, stratified, worn and rounded, with a few short, deep furrows (probably artificial). Sandstone. 22 in. × 15 in. (?) × 6 in. (?)

130. Angular block, very little worn. Coarse sandstone: probably millstone grit. 17 in. × 12 in. × 7 in. (?)

131. Roughly rectangular, surface uneven and broken, but somewhat worn. Hard sandstone, with plant-remains (?): probably jurassic. 14 in. × 11 in. × ?.

132. Rounded, worn pebble. Sandy limestone: probably jurassic. 9 in. × 7½ in. × 5½ in.

133. Rounded, worn, flattish fragment. Ferruginous, slightly calcareous sandstone: probably neocomian. 10 in. × 8½ in. × 3 in.

134. Little-worn slab. Ferruginous sandstone: probably neocomian. 12 in. × 4½ in. × 2 in.

135. Worn, smoothed, broken slab, slightly scratched. Limestone with fossils: probably jurassic. 7 in. × 7 in. × 2 in.

136. Rough, broken pebble. Limestone, with fossils: jurassic. 4 in. × 4 in. × 3 in.

137. Broken piece, much rounded on original surface; apparently a piece of a nearly spherical boulder; a few scratches and grooves. Limestone: probably jurassic. 9 in. × 6 in. × 3½ in.

138. Rough, broken, somewhat smoothed on one side. Coarse grit, with small, rounded quartz pebbles: millstone grit. 6½ in. × 6 in. × 4 in.

139. Flat slab, angles rounded and whole surface smoothed, except lower side. Fine hard sandstone: possibly carboniferous. 6½ in. × 6 in. × 2 in.

140. Triangular, broken fragment; one face well-smoothed, and scratched and grooved in various directions. (Very probably these markings are not ancient). Limestone: probably jurassic. $8\frac{1}{2}$ in. × 7 in. × 2 in.

141. Worn and smoothed, wedge-shaped. Felstone, either orthoclase-felsite or porphyrite. ? Cheviots or S. Scotland. $7\frac{1}{2}$ in. × $5\frac{1}{2}$ in. × 3 in.

142. Rough, angular slab (possibly not a boulder). Limestone, with fossils: probably mesozoic. 19 in. × 9 in. × ?.

143. Similar to 142. 2 ft. 6 in. (?) × 8 in. × ?.

144. Broken, worn piece. Limestone: carboniferous. 8 in. × 9 in. × 6 in.

145. Rounded, worn pebble. Very hard fossiliferous limestone: probably Lias Marlstone. 9 in. × 7 in. × ?.

146. Rough, irregularly-shaped pebble, very slightly worn. Sandy limestone: very like Lias marlstone, with pecten (? æquivalvis). 9 in. × 6 in. × $5\frac{1}{2}$ in.

147. Rounded, worn, flattish boulder. Fossiliferous limestone: probably identical with 140. 12 in. × 10 in. (?) × 6 in.

148. Smoothed, rounded, and slightly scratched, broken piece. Limestone: carboniferous or mesozoic. $8\frac{1}{2}$ in. × 7 in. × 5 in.

149. Angular, rough, cubical block, very little worn. Limestone: small pecten on surface. $16\frac{1}{2}$ in. × 12 in. × 11 in.

150. Rough, flat-topped slab, worn on lower side, appears to have been broken on upper face. Chiefly decomposed felspar, with a fine chloritic mineral, decomposed mica or possibly hornblende. So poor in quartz as hardly to be worthy of being called gneiss. 2 ft. 0 in. × 1 ft. 2 in. (?) × $7\frac{1}{2}$ in.

151. Worn, rounded, surface uneven. Basalt. 8 in. (?) × $7\frac{1}{2}$ in. × 6 in.

152. Broken, rough, angular fragment. Calcareous sandstone, with serpula, ostræa or exogyra, &c. Jurassic. $12\frac{1}{2}$ in. × 10 in. × ?.

153. Rounded, cuboidal block, surface rough. Calcareous mudstone, with ostræa or gryphæa. Jurassic, very like Lias Marlstone. 13 in. × $9\frac{1}{2}$ in. × ?.

154. Rounded, with nearly flat faces. Coarse ferruginous sandstone, with rounded quartz grains. Neocomian. 15 in. × 10 in. × ?.

155. Flat slab, angles worn. Limestone: probably carboniferous. $10\frac{1}{2}$ in. × 10 in. × 3 in.

156. Angular, broken slab. Limestone: jurassic. 12 in. × 10 in. × 3 in.

157. Much smoothed, worn slab. Fine sandstone: probably carboniferous. 9 in. × 9 in. × 3 in.

158. Angular slab, possibly slightly worn. Argillaceous limestone, with fossils: probably Lias. 11 in. × 10 in. × 4 in.

159. Worn, faces nearly flat, and angles a little rounded. Ferruginous sandstone: probably neocomian. 13 in. × $10\frac{1}{2}$ in. × 7 in.

160. Flat, worn slab. Sandstone: perhaps carboniferous. $11\frac{1}{2}$ in. × 9 in. × 5 in. (?)

161. Triangular, worn slab, smooth, and angles but little rounded. Ferruginous sandstone: probably neocomian. 11 in. × 7 in. × 6 in.

162. Flattish, worn block. Fine, hard sandstone: probably carboniferous. 10 in. × $5\frac{1}{2}$ in × $4\frac{1}{2}$ in.

163. Irregularly triangular, smooth, bedded slab. Fine, hard ferruginous sandstone: probably carboniferous. 9 in. × $6\frac{1}{2}$ in. × 4 in.

164. Much worn and rounded pebble, with a few scratches. Compact, white sandstone. 10 in. × 6 in. × ?.

165. Rounded, broken piece. Fine sandstone. 9 in. × 7 in. × 4 in.

166. Rectangular, broken slab (probably not a boulder). Oolitic limestone. 12 in. × 10 in. × 3 in.

167. Rounded, smoothed and worn. Hard sandstone: probably neocomian. 10½ in. × 9 in. × ?.

168. Rounded, worn. Fine sandstone: probably jurassic. 11 in. (about) × 7½ in. × ?.

169. Wedge-shaped, worn pebble. Ferruginous, calcareous sandstone: probably jurassic. 7½ in. × 6 in. × 4 in.

170. Rough, slightly worn. Limestone, with serpula: jurassic. 8½ in. × 7 in. × 6 in.

171. Rough slab, little worn. Ferruginous sandstone: neocomian or possibly inferior oolite ironstone. 13 in. × 6½ in. × 8½ in.

172. Prism-shaped, faces flat and smoothed, angles a little worn. Basalt. 10 in. × 5½ in. × 5 in.

173. Worn slab. Coarse grit: perhaps neocomian. 10½ in. × 7½ in. × 3 in.

174. Broken slab, hardly worn. Sandstone. 9½ in. × 8 in. × 3½ in.

175. Rounded, nearly spherical, smoothed. Limestone, with serpula, &c. Jurassic. 11 in. × 8 in. × 7 in.

176. Worn, rounded, smooth pebble. Hard sandstone. 8½ in. × 7 in. × 3 in.

177. Irregularly-shaped, worn, angles but little rounded off. Basalt. 12½ in. × 7 in. × 6½ in.

178. Slightly worn fragment of a slab. Rather ferruginous sandstone. 11½ in. × 5 in. × 3 in.

179. Long, smoothed and worn boulder. Sandstone. 11½ in. × 5½ in. × 3 in.

180. Rough, irregular, little-worn pebble. Fine sandstone: probably carboniferous. 7 in. × 7 in. × 6 in.

181. Flat, broken slab, little worn. Fine sandstone: possibly jurassic. 13 in. × 9½ in. × 5 in.

182. Rounded, worn, smoothed, nearly oval pebble. Sandstone: probably neocomian. 8 in. × 6 in. × 5½ in.

183. Rectangular, little-worn block. Fine, hard sandstone: probably carboniferous. 11 in. × 6½ in. × ?.

184. Worn slab. Coarse sandstone or grit: millstone grit, almost certainly. 11 in. × 9 in. × 4 in.

185. Wedge-shaped, worn pebble, with flat faces, and angles little worn. Fine, ferruginous sandstone: probably neocomian. 9½ in. × 7 in. × 4 in.

186. Irregularly-shaped, smoothed and worn. Basalt. 16 in. × 9 in. × 8 in.

187. Worn, rough block. Fine ferruginous sandstone: probably neocomian. 10 in. × 6 in. × 6 in.

188. Worn, smoothed. Fine sandstone: possibly jurassic. 2 ft. 0 in. × 1 ft. 3½ in. × ?.

It will be observed that none of these specimens are local. The general derivation is from the Oolites of the Midlands and from Carboniferous and other rocks of more northern districts.

Denbighshire.—The Committee have received the following communication from Mr. D. Mackintosh, F.G.S. :—

I lately found a large boulder of Eskdale granite 164 feet above the highest level of the parent rock *in situ.* It lay amidst many millstone grit boulders on the summit of the mountain ridge south of Minera, Denbighshire, at a height of about 1,450 feet above the sea.

Height above the Sea of Erratic Chalk-flints.—I lately found many chalk-flints associated with pebbles of Eskdale granite, &c., more than 1,100 feet above the sea on the E. side of the mountain south of Minera. Mr. John Aitken has lately informed me that he found *unworked* as well as worked chalk-flints more than 1,000 feet above the sea on the western side of the Pennine hills. It is well known that chalk-flints occur in the drift on Moel Tryfan in North Wales up to a great altitude. During late visits to the mountain I found them as high up as 1,350 feet above the sea, or about 350 feet higher than the chalk *in situ* in Ireland. That the chalk-flints were transported by ice, and that they are not the insoluble residue of chalk which once existed *in situ*, is evident from the extent to which they are intimately associated with undoubted erratic stones, and from their not being associated with insoluble silicified chalk fossils. It is at the same time very difficult to conceive of chalk itself having once extended over an area so large as that which is more or less strewn with flints without leaving patches in protected situations.

Passage of Boulders through Gaps.—Many large boulders from the Arenig Mountains have found their way through the gap in the Minera mountain range which is traversed by the road leading from Mountain Lodge (W. of Ruabon), to the World's End (N. of Llangollen.)[1]

The Committee earnestly repeat their request for the assistance of local observers to enable them to catalogue the rapidly disappearing Erratic Blocks of the country with as much completeness as possible. A large part of the most interesting specimens are especially liable either to be destroyed as nuisances on the land, or utilised as building materials ; and unless especial attention be paid to them during the next few years, no accurate record of their position and character will remain.

Second Report of the Committee, consisting of Professor A. LEITH ADAMS, the Rev. Professor HAUGHTON, Professor BOYD DAWKINS, *and* Dr. JOHN EVANS, *appointed for the purpose of exploring the Caves of the South of Ireland.*

Report on the Caves and Kitchen-middens near Cappagh, Co. Waterford, by R. J. USSHER.

SINCE the explorations reported to the British Association last year, made in a cave at Carrigagower near Middleton, in company with Mr. J. J. Smyth, of Rathcoursey, I had the pleasure of excavating in his

[1] In and E. of that gap they are strewn in a manner more easily explained by floating ice than land ice, as it is more difficult to conceive of land ice (after passing through the gap), continuing its course in a narrow stream for several miles in an easterly direction, than it is to conceive of floating ice doing the same.

company a spot on the townland of Ballyhonock, not far from Castle Martyr, in the Co. Cork, where in a piece of rocky uncultivated ground we found a kitchen-midden containing bones of domesticated animals, charcoal, sea-shells, a quern stone, sharpening stones, and several other relics of man. Beneath the above, or mixed with them, we found a number of human bones, both of adults and young children (there were six or eight of the latter), apparently the remains of bodies that had been entire when deposited there. Previous to our excavations there had been discovered at the same spot one of the dumbbell-shaped stones, cupped at each end, that have been found in other places in Ireland. It is now in the Cork Institute.

I also excavated the kitchen-midden of a rath at Bewley, in the Co. Waterford, where I found, among charcoal, slag, burned stones and numerous broken bones of ox, goat, pig, horse, and red deer, a quantity of broken pieces of hand-made pottery of rude make, full of quartz grains and representing a number of vessels of considerable size, charred and burned sometimes internally and sometimes externally. This pottery was all broken, and generally in a most friable condition. Shells of the fresh-water mussel were also found in this refuse-heap, and a human metacarpal or metatarsal bone; but the most remarkable object I met with there was a rude stone hatchet formed from a waterworn flattish stone, adapted for the purpose by breaking it across and chipping its broad broken extremity to an edge, two deep indentations being also made at opposite sides, evidently to hold a ligature or attachment for a handle.

Continuing my researches along the scarp where the bone-cave of Ballynamintra is situated, I found in and around the mouth of a small cave on the townland of Ballynameelah another kitchen-midden with bones of the usual domestic animals and red deer, charcoal, slag, flint-chips, sea-shells, some pieces of iron, pieces of a jet bracelet, a fine ring of bronze, probably an ear-ring, portion of a bone comb of a type to be described, a carved bone whorl, and a number of whetstones.

In the month of May last I commenced operations in a rath situated on a high rocky knoll that forms the scarp opposite to that containing the bone cave. This rock is called Carrigmurish, or the Rock of Maurice. A tradition exists that a highwayman named Maurice Conway lived there, who was put to death on the rock for his crimes. The rath consists of a ring fence in a ruinous condition, and contained a depression flanked on one side by a rock that appeared hollow beneath. This hollow I found at once to contain the kitchen-midden of the rath, and now that it is excavated to the depth of some thirty feet it is shown to have filled a cave, descending at an angle of 50° or so, of considerable size. This cavity was choked with earth and stones containing large quantities of charcoal, bones, and other relics. The larger bones were almost all broken, to extract the marrow. The animals represented were a small breed of oxen (the foreheads of which were broken in), pigs, goats, asses, red deer, and in a few instances dogs, cats, and domestic fowl. Some of the canine bones were of large size. Pieces of the antlers of red deer were plentiful. These were generally cut in lengths with a saw, the cuts being made at both sides and the piece then broken off. Several articles of antler were found, marling-spikes or piercers, pins, whorls, and beads. An interesting series of narrow scoops occurred, one class of which are made of the tibiæ of goats and another of those of fowl. Pins of the latter bones were also plentiful, but wanted the polish observable on those made of antler, which were more carefully finished and had either a notched groove, an eye, or a head otherwise carved for attachment by a string. Of the bone articles there are several combs with teeth on both sides, whose middle portion is formed of three plates of bone fastened together with rivets of bone and in one instance of iron. A knife-handle of antler, polished and ornamented with small circles, held an iron blade, some of which remains. A portion of a large polished jet bracelet, as well as of a smaller one, was also found, and two bits of coloured iridescent glass.

A bronze pin and other objects of bronze were also found.

Iron objects were numerous, especially small curved knife-blades thick at the back. There is one long slender knife or poniard, a spear-head eleven inches long, and the head of a smaller spear, a series of slender rods and pins of iron, two of the latter with iron rings attached to them, large-headed iron nails, a rude buckle, a portion of a crucible or helmet, and the share of a wooden plough with wood adhering. One of the most interesting objects of iron is a small saw with the end curved up like that of a skate. This is inserted in a wooden back, which doubtless served as the handle, and explains why the pieces of antler were not cut through, as would be done by a modern saw-blade.

Stone objects were also numerous; a quern, a round mace or hammer-head with a hole for inserting a handle, spindle-whorls, a small stone bead, a large assortment of whetstones, one of which was beautifully cut and pierced by a hole for attachment, burnishing stones, globular and disc-shaped pebbles, which probably served as sling-stones, and one of which has a cross cut on it, also a number of marine pebbles, probably selected for their colouring, and crystals. With these sea-pebbles may be mentioned shells of oysters, limpets, whelks, cockles, scallops, and other marine molluscs. Slabs of sandstone, and in some cases of silurian rock, foreign to the locality, frequently occurred, arranged evidently for hearths, at different levels in the cavity, which doubtless became buried under subsequent débris.

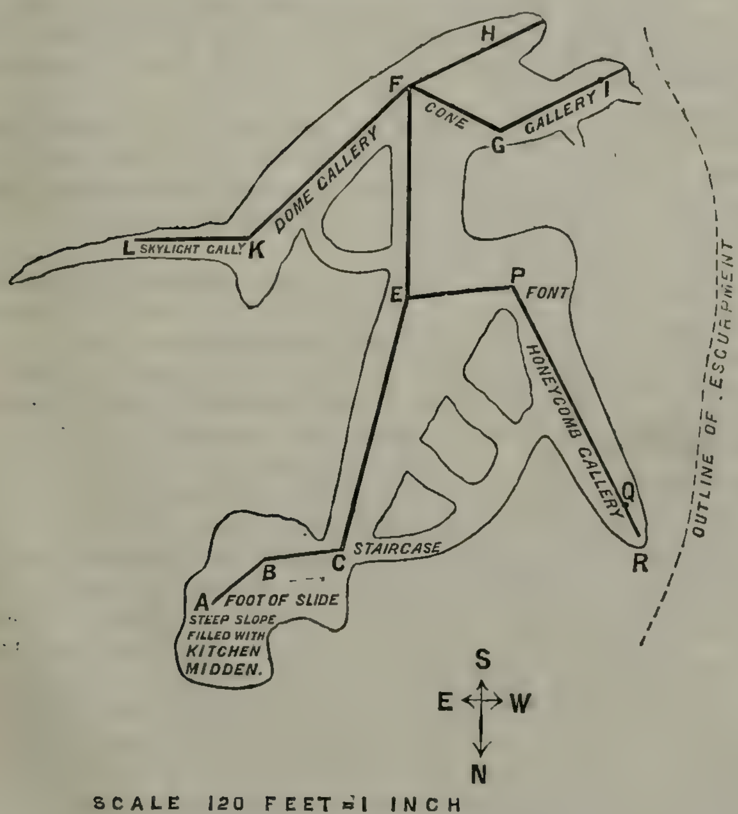
A large amount of the kitchen-midden is believed to remain undisturbed, probably quite as much as the excavated material. At a depth of more than twenty feet the cavity was found to extend very much and not to be filled with earth. On exploring the open part with lights, large chambers were discovered, from one of which by a steep descent we made our way into the extensive system of galleries shown in the accompanying plan, which has been dialled and laid out by Mr. Duffin, County Surveyor, who has given me the most valuable assistance. The dialling shows the directions and lengths of the chambers and galleries already known, but time did not allow of making a detailed survey. When the dialling was laid out on the surface it was found that the point R is very near the face of the scarp, and that persons within the cave could here communicate by sounds with those without. Here a convenient entrance can be made into the caverns. On the surface of the different galleries were found broken bones of domestic animals similar to those in the kitchen-midden, as well as charcoal. As a rule a stalagmite floor extends throughout, exhibiting in places large pillars, domes, cones, dammed-up pools of clear water, and similar phenomena. This stalagmite floor rests on a deposit of cave-earth several feet in depth, which it is desirable to excavate and remove to daylight for thorough examination, considering the interesting remains discovered in the adjoining cavern. This work will, however, be a matter of great labour, and require considerable time.

The excavation of the kitchen-midden above described was difficult, owing to the depth from which the large amount of material had to be lifted, in a box or buckets, by means of a pulley, windlass, and other plant.

The grant of 10*l.* made in 1879 has been expended, as well as a great part of another grant of 50*l.* made by the Royal Irish Academy. To thoroughly explore all the galleries would cost a very large sum, but if the British Association were to grant us a sum of 50*l.* we could make a good commencement, quite sufficient to show what the fauna of the cave-earth may have been.

Rough plan of Caverns at Ballynamintra, with dialling by W. E. L'Estrange Duffin, *County Surveyor.*

Dialling of Carrigmurish.



Report of the Committee, consisting of Sir F. J. Bramwell, Dr. A. W. Williamson, Professor Sir William Thomson, Mr. St. John Vincent Day, Dr. C. W. Siemens, Mr. C. W. Merrifield, Dr. Neilson Hancock, Mr. Abel, Captain Douglas Galton, Mr. E. H. Carbutt, Mr. Macrory, Mr. H. Trueman Wood, Mr. W. H. Barlow, *and* Mr. A. T. Atchison, *appointed for the purpose of watching and reporting to the Council on Patent Legislation.*

The Bill of this Session, 1881, by Mr. Anderson, Mr. Brown, Mr Hinde Palmer, and Mr. Broadhurst, was read and considered.

This Bill, which as it stands is a mere sketch, and not likely to prove a working piece of legislation, is identical with the Bill introduced last year by the same gentlemen, and referred to in the last Report (*B. A. Report*, 1880, p. 318) of this Committee. It was, however, read a second time in the House of Commons and consequently reached a further stage than in 1880.

The Bill proposes the appointment of a Chief Commissioner and assistants. It would reduce the fees considerably, that on application to 10*s*. and on sealing to 1*l*. It extends the period of provisional protection to twelve months. It gives a patentee power to add (apparently by way of supplement) to his original patent.

The Committee certainly approve the proposal to appoint paid Commissioners. They think the proposed reduction in fees much too large. They approve the principle of letting a patentee amend his patent, but it would be necessary that proper provision should be made. The clause in the Bill would be quite unworkable.

The Committee have also to report that a carefully prepared Bill has been published by the Council of the Society of Arts for discussion, with the view of its being introduced into Parliament next year.

The principal alterations in the law which would be made by the Society of Arts' Bill are shown in the following memorandum, which appeared in the Journal of the Society for August 12, 1881:—

Commissioners of Patents.—The Patent-office would be removed from under the charge of the present Commissioners, who are the Lord Chancellor, the Master of the Rolls, and the Law Officers. Three Commissioners would be appointed on account of their special knowledge.

Application for Letters Patent.—Method of granting same.—The method of application for a patent would be somewhat as follows:—The applicant would file a provisional specification, which would be referred to examiners appointed for the purpose. They would see that the invention was proper subject-matter for a patent; that the specification fairly described the invention, and that it was generally intelligible and properly drawn. They would not inquire into novelty or utility. They would report, and their report would be shown to the applicant before being seen by the Commissioners. The applicant would then have an opportunity of conferring with the examiners as to any required alterations. Provisional protection would be granted immediately on receipt of the application, and would last for nine months. Before the end of that time the applicant would be required to file a complete specification, fully describing his invention. This would be referred to the examiners, and treated in the same manner as the provisional specification. The applicant would be enabled to amend his specification in accordance with the recommendation of the examiners, and on his doing so a patent would be granted. If the examiners reported that the application was in respect of matters which could not properly be made the subject of a patent, and if the applicant still persisted, a patent would still be granted, but the objections of the examiners would be endorsed upon the specification.

Duration of Patent.—The duration of Letters Patent would be increased to seventeen years—the duration being as now contingent upon the payment of fees at or before the expiration of each period.

Fees.—The fees would be half the present amounts, namely :—

	£	s.
Fee for Provisional Protection	2	10
Fee for Grant	10	0
Fee at expiration of fourth year	30	0
Fee at expiration of eighth year	60	0

Existing System.—Under the present law there is practically no examination whatever. Applications for patents are referred to one of the two law officers, who reports whether a warrant may be issued for the granting of Letters Patent. The only point upon which the law officer decides is whether the invention is proper subject-matter for a patent, *i.e.* whether it comes within the definition of the Statute of Monopolies (21 Jac. I., cap. 3) of being 'a new manufacture within this realm.' The complete specification, upon which the patent is really granted, is never examined at all by anybody.

Subject-matter.—The following is the definition of 'subject-matter' adopted in the Bill :—

(*a*) Any manufacture or any product not being a natural product;

(*b*) Any machine or any means of producing any manufacture product or result;

(*c*) Any process or method of producing any manufacture product or result;

(*d*) Any part of a machine means process or method of producing any manufacture product or result.

At present the ancient definition of the Statute of Monopolies is in force, but, as a matter of fact, the question of subject-matter depends wholly on the decisions of the Courts.

Opposition.—Under the proposed Bill, opposition to the granting of Letters Patent would be limited to persons who could state that the applicant had obtained the invention from them by means of fraud. Under the present law any person can oppose, the general ground of opposition being that the person opposing already has a patent for the same or nearly the same invention.

Amendment.—The Bill provides that the inventor should be entitled to amend his specification after it had been first filed. Under the present system this power is very restricted.

Prolongation.—It is proposed to continue the system of prolonging patents in special cases, the Bill being framed in such a manner as to give greater facility for this than now exists. Under the present system, prolongations are granted by the Privy Council, and are considered a matter of special favour, whereas the effect of the new Bill would, it is hoped, be to give them as a right to any inventor who could show just cause for having his privilege prolonged, on the ground of his not having had sufficient reward, or the time having been insufficient to enable him to bring his invention into action, or similar grounds. The period for which a patent could be prolonged would be diminished by the three years which the Bill would add to its original term.

Obligatory Licenses.—The Bill would compel a patentee to grant licenses in cases where it could be clearly shown that the invention was not being worked in such a way as to supply the reasonable wants of the public; but the clause has been so worded as to prevent any improper interference with the rights of the patentee over what is considered to be his own private property.

Trial of Patent Cases.—The Bill would provide for the trial of patent cases in an entirely new manner. They would be tried, in the first instance, before one of the Commissioners, and an appeal would lie to the whole body. The Commissioners would have power to call in assessors, and would have such other powers as would enable them to try the cases fully. It is hoped that this would greatly simplify the patent litigation, and would prevent the enormous expense which is now incurred by having to bring complicated questions of law and fact before a jury, who are probably ignorant of the scientific or mechanical considerations involved. It may be noted that one great source of expense is the preparation of models, which are only necessary to illustrate mechanical questions to persons unaccustomed to deal with such questions. For experts in such matters, drawings would be sufficient; indeed, an engineer would generally much prefer proper drawings to any model of a machine.

Anticipation.—It is proposed that a mere publication more than thirty years old, unaccompanied by use within the thirty years, should not be considered sufficient to invalidate a patent. The object of this is to remove the hardship, which now not infrequently occurs, of a patent being invalidated, or a patentee being put to great expense in order to prove his claim, by the discovery of some ancient and probably incomplete description, a description which in many cases could not have been put into operation at the time it was made for want of necessary appliances to carry it into effect.

Patents to Foreigners.—It is proposed that patents should be granted to foreigners, or persons resident abroad, on precisely the same terms as those on which they are granted to British subjects resident in the United Kingdom. At present patents are granted to British subjects in respect of communications from abroad; that is to say, the theory is, a person travelling abroad sees a useful invention, brings it home, and patents it in England, such person not being, in any sense, the inventor. In practice, patents for communications from abroad are nearly always taken out by patent agents, whose clients are resident out of the country, and the patent, as soon as it is taken out, is assigned to the real foreign inventor. Cases of injustice have occurred through the action of this system, in which a patent has been granted to a person who had no moral right to it, but who anticipated the original inventor in obtaining the English patent.

Effect of Foreign Patents on English Patents.—At present an English patent lapses at the expiration of any foreign patent taken out by the same inventor for the same invention. It is proposed in the Bill that English patents should not in any way be affected by foreign patents.

The Committee request that they may be re-appointed, in order to watch the progress of this Bill through Parliament, as well as that of any other Bill for the amendment of the Patent Law which may be introduced.

The Committee have not expended any of the sum of *5l.* placed at their disposal last year, but they would be glad to have the grant renewed.

Report of the Anthropometric Committee, consisting of Mr. F. GALTON, Dr. BEDDOE, Mr. BRABROOK (*Secretary and Reporter*), Sir G. CAMPBELL, Dr. FARR, Mr. F. P. FELLOWS, Major-General PITT-RIVERS, Mr. J. PARK HARRISON, Mr. JAMES HEYWOOD, Mr. P. HALLETT, Professor LEONE LEVI, Dr. F. A. MAHOMED, Dr. MUIRHEAD, Sir RAWSON RAWSON, Mr. CHARLES ROBERTS, *and the late* Professor ROLLESTON.

[PLATES III. AND IV.]

1.—The Committee were first appointed in 1875, and instructed to continue the collection of observations on the systematic examination of heights, weights, &c., of human beings in the British Empire, and the publication of photographs of the typical races of the empire. It may be convenient to recapitulate briefly what the Committee have done in previous years.

2.—In the first year they prepared schedules and instructions and had them printed, and purchased a small outfit of instruments to send to places where measurements were to be made. The co-operation of inspectors of the army, of the navy, of factories, and of pauper schools was secured.

3.—In the second year the Committee obtained a series of measurements of the 2nd Royal Surrey Militia from Colonel Lane Fox (now General Pitt-Rivers) and circulated copies of his report as a model for other observers. They further revised the instructions, prepared a book of lithographed patterns of hair colours, added to the collections of instruments for lending, and initiated the work of collecting typical photographs.

4.—In the third year the collection of statistics was actively proceeded with, and returns were obtained of a few well-defined classes, as boys in Westminster school, letter-sorters in the Post Office, criminals, &c. Tables were prepared from these, and a Report by Mr. Galton on the returns of criminals was printed and circulated. Progress was made in the collection of photographs.

5.—In the fourth year the Committee continued the collection and tabulation of observations. They had by that time obtained statistics of about 12,000 individuals, which were sufficiently complete to justify the publication of tables of average height and weight, and of the ratio of weight to height. They had been furnished by the Warden of Christ's Hospital with the records in his possession which enabled Sir Rawson Rawson, one of the members, to construct a series of tables, serving as a model for similar observations. Mr. Roberts prepared for the Committee a series of tables and charts, showing the relation of height and weight in the several classes of the English population, as compared with the observations of Americans and Belgians published by Drs. Bowditch, Baxter, and Quetelet respectively.

6.—In the fifth year the Committee were able to double the number of observations, and to reduce them to order by adopting a scheme of classification. They selected from the returns those which related to a standard class living under the most favourable conditions with respect to fresh air, exercise, and wholesome and sufficient food, and prepared a series of tables relating to that class. They also digested the returns relating to the colour of hair and eyes in the standard class, and summarised the statistics of height and weight from persons of country origin and town origin respectively. They availed themselves of the observations made during several years at Marlborough College to show the usefulness of such systematic records.

7.—In the present year, the sixth of their existence, the Committee have not carried on operations under favourable circumstances. The returns obtained in relation to the several classes are now of sufficient number to make it desirable to subject them to scientific arrangement by skilled computers, but the small fund at the disposal of the Committee (30*l.*) has not been sufficient to enable this to be done completely.

8.—The same cause has prevented the incurring any expense in grants towards actual observations, which, as they involve skill and care and time, ought, in many cases, to be paid for. The whole of the returns collected during the year have been due to obliging voluntary assistance.

9.—The Committee think it an important part of their duties to show how observations should be made, and how they should be used when obtained. From this point of view, they are inclined to hope that their labours have been very successful.

10.—It is confidently anticipated that many of the persons who have been furnished with the forms and instructions adopted by the Committee, and to whom these reports are accessible, will proceed with the collection and recording of observations on the definite system laid down, and that, by this means, valuable results will be obtained and made available even after the Committee have ceased operations.

11.—This remark applies particularly to the case of the public and other schools and institutions which have furnished information to the Committee, as recorded in the present and previous reports. In each of these it is hoped that the practice of keeping an anthropometric record will be continued.

12.—On page 3 is a statement of the additional returns which have been furnished to the Committee during the present year.

13.—The special thanks of the Committee are due to the contributors, mentioned in the list, whose zealous assistance in a matter necessarily involving a great expenditure of time and trouble deserves most hearty acknowledgment.

14.—Adding these returns to those referred to in the previous reports, the aggregate number of original observations furnished to the Committee is as follows:—

Year	Sex	Number of observations					
		Of birth-place and origin	Of age, height, and weight	Of colour of hair and eyes	Of girth of chest	Of strength of arm	Of eyesight
1879	Male	5,254	11,745	4,011	6,321	2,131	1,368
1880	Male	3,206	11,956	3,511	5,766	1,686	1,260
1881	Male	796	5,877	867	789	1,521	315
1881	Female	368	403	403	403	338	13
Total . .		9,624	29,981	8,792	13,279	5,676	2,956

15.—Upon the main branch of the inquiry, therefore, that of the relation of height and weight to age, the Committee have collected, in round numbers, 30,000 original observations. To these have to be added the 50,000 or more observations independently collected by Mr. Charles Roberts, one of the most active members of the Committee.

List of Observations collected during the Year 1881.

Sources of Information	By whom furnished	Number of Observations						
		Sex	Birth-place and Origin	Age, Height and Weight	Colour of Hair and Eyes	Girth of Chest	Strength of Arm	Eyesight
1. Medical Students (Leeds)	Mr. F. Greenwood	Males	57	57	57	—	—	—
2. St. Stanislaus College (Ireland)	Rev. W. Delany	,,	100	100	100	100	100	100
3. York Quaker School	Mr. E. Clarke	,,	—	5000	—	—	—	—
4. Yarlet Hall School	The Head Master and Gymnastic Master.	,,	73	73	73	73	73	—
Ladies' Schools.								
5. North London College	Mrs. Bovell Sturge, M.D.	Females	73	73	73	73	73	—
6. Orme Girls' School, Newcastle, Stafford	Miss Martin	,,	—	35	35	35	—	—
7. Ladies' College, Guernsey	Miss Eaton	,,	30	30	30	30	—	13
8. Roan School, Greenwich	Miss Blackmore	,,	265	265	265	265	265	—
9. Letter-sorters, &c.	Dr. Waller Lewis	Males	—	—	—	—	1159	—
Rifle Volunteers.								
10. Cumberland	Dr. Knight	Males	55	55	55	55	—	55
11. Lancashire	Major Greenall	,,	28	28	28	28	28	28
12. Lancashire	Dr. Barrow	,,	245	245	245	245	—	—
13. Glamorgan (further instalment)	Dr. Evan Jones.	,,	6	6	6	6	6	6
14. Militia (West Norfolk)	Major Massy	,,	—	81	81	81	—	—
15. Industrial Classes (Cardiff)	Dr. Taylor	,,	80	80	70	75	55	—
Industrial Schools.								
16. Anerley (North London Pauper Schl.	Mr. J. Marsland	,,	100	100	100	100	100	100
17. Bristol	Dr. Beddoe	,,	26	26	26	26	—	26
,,	,,	,,	13	13	13	—	—	—
,,	,,	Females	13	13	13	—	—	—
			1164	6280	1270	1192	1859	328

Table A.—Showing the number of observations of Height and Weight collected by the Committee at each age in the several classes, including some of the returns placed at its disposal by Dr. Beddoe and Mr. Chas. Roberts.

Age in years	Height: Class 1	Height: Class 2	Height: Class 3	Height: Class 4	Height: Class 5	Height: Class 6	Weight: Class 1	Weight: Class 2	Weight: Class 3	Weight: Class 4	Weight: Class 5	Weight: Class 6
10–	101	313	783	336	419	959	92	211	—	—	—	108
11–	242	687	597	240	341	951	185	393	—	—	—	96
12–	490	902	395	193	325	645	369	410	—	—	—	115
13–	869	857	403	614	—	531	621	353	—	640	—	106
14–	966	800	9	1653	1	1414	748	304	—	1396	—	75
15–	974	544	515	1464	3	230	652	244	676	1446	3	44
16–	1102	110	177	1391	6	164	834	55	169	1177	6	24
17–	1852	107	75	711	20	92	1705	38	80	673	21	52
18–	1724	62	148	371	31	579	1638	39	135	338	29	359
19–	951	63	143	277	29	579	940	69	140	289	31	379
20–	461	61	183	175	35	461	451	52	175	173	33	285
21–	364	51	177	165	35	381	365	51	164	157	31	281
22–	227	53	127	109	33	345	215	51	167	109	33	243
23–	114	59	274	145	61	326	112	57	279	103	54	260
24–	57	62	258	140	42	317	56	57	250	120	37	281
25–	}	47	218	92	31	}	}	45	224	61	32	}
26–	}	47	194	74	44	}	}	46	192	58	32	}
27–	} 107	27	162	66	44	} 981	} 115	26	171	56	45	} 958
28–	}	33	208	59	42	}	}	33	213	50	30	}
29–	}	26	163	53	33	}	}	26	161	46	30	}
30–	} 52	85	745	180	156	587	} 48	87	700	153	144	}
35–	}	82	631	111	110	419	}	80	631	105	92	}
40–	} 46	43	551	64	82	261	} 44	39	541	66	75	} 1901
45–	}	36	392	16	64	162	}	33	371	47	60	}
50–	—	16	147	22	22	222	} 18	16	129	21	20	}
60–70	—	—	34	—	2	98	}	—	24	—	2	}
	10,699	5,173	7,709	8,721	2,011	10,704	9,208	2,815	5,592	7,284	840	5,567

16.—Mr. Roberts has rendered his colleagues very essential help by the preparation of the diagrams and a great number of the elaborate tables in the former Reports of the Committee, and has contributed to the present Report the paper on the general result of the observations, which is given in the Appendix.

17.—Mr. Roberts's Tables (I.–IV.) show the general result of the observations collected by the Committee as to (1) height, (2) weight, (3) chest-girth, (4) strength.

18.—The height of 38,953 persons is recorded in Table I., the horizontal black lines in which indicate the curve of growth formed by the 'mean' height at each age, which is 3 feet 5 inches at the age of 5, and becomes 5 feet 8 inches at the age of 50.

19.—The weight (with clothes, for which about 7 lbs. may be allowed) of 26,560 persons is recorded in Table II. The horizontal black lines in this Table indicate the curve of increase in weight formed by the 'mean' weight at each age, which is 4 st. 9 lbs. at the age of 10, and becomes 11 st. 8½ lbs. at the age of 70.

20.—The chest-girth of 17,883 persons is recorded in Table III., the horizontal black lines in which indicate the curve of increase formed by the 'mean' chest-girth at each age, which is 26 inches at the age of 10, and becomes 36½ inches at the age of 40.

21.—The strength, as indicated by the drawing power of the arm, in 5,039 persons is recorded in Table IV., the horizontal black lines in which indicate the curve formed by the variations of the 'mean' drawing power at the successive ages, rising from 35 lbs. at age 11 to 80 lbs. at ages 25–30, and falling again to 70 lbs. at the age of 50.

22.—In using Mr. Roberts's tables, however, it is important to bear in mind that he employs the term 'mean' not in the ordinary sense of an arithmetical mean or average, but as representing 'the value at which the largest number of observations occur,' or that of 'greatest frequency.' The arithmetical average is found by him in adults to exceed the 'mean' in general by about half an inch.

23.—In Tables V. and VI. Mr. Roberts is able to show the results of a comparison as to the 'average' height and weight of the several classes of the population, distinguished as (1), the professional classes, including town and country; (2), the commercial classes in towns; (3), the labouring classes in the country; (4), the artisans in towns.

24.—Table V. relates to height, which is taken without shoes. The relative position of the four classes stands in the order stated; classes 1 and 2 being taller, and classes 3 and 4 shorter, than the general population. This relation is maintained throughout, and the table affords material for study as to the comparative effects of occupation and town and country life on growth.

25.—Table VI. relates to weight, which is taken with clothes. The relative position of the four classes still stands nearly in the same order, class 1 being heavier and class 4 lighter than the general population, but class 3 very nearly coincides with the general average, and is in general superior in weight to class 2. In other words, the rural occupation of the country labourer gives him the advantage in weight over the town tradesman, though the latter has the advantage in height.

26.—Class V. of the classification adopted by the Committee in the Report for 1880—the industrial workers or sedentary trades in towns; and Class VI., the specially-selected occupations, have not furnished returns in sufficient number to be available for comparison.

27.—The chairman of the Committee, Mr. Francis Galton, contributes to the Appendix to this Report a paper on the range in height, weight, and strength of the different classes at every age. He measures the range, not between the maximum and minimum values recorded, which afford no safe basis for comparison, but through an extension of the principle by which the so-called 'probable error' is ascertained. Thus, he first arranges the cases in the order of their magnitude, then he cuts off a certain fractional portion of them from either end of the series, and measures the difference between the maximum and minimum of the intermediate group. The ranges given are between the upper and the lower tenths and between the upper and the lower fourths, the value of the latter range being identical with twice the 'probable error.'

28.—Inspector-General Lawson contributes to the Appendix to this Report a valuable paper giving the results of the earlier portion of the observations furnished to the Committee on eyesight.

29.—The total number of observations of eyesight collected by the Committee has been 2,956; many of which, as will be seen by Dr. Lawson's paper, are not considered trustworthy. Sufficient, however, have now been derived from various independent sources to form a fair average.

30.—This inquiry as to eyesight has led the Committee to consider the very important question of colour-blindness, which has been ascertained in Germany and America to affect 1 in 25 of the male population, and which probably exists in this country to a greater extent than is suspected by most people.

31.—To facilitate the collection of statistics relating to colour-blindness, the Committee accepted an offer which a member, Mr. Roberts, was enabled by the kindness of the Norwegian professor, Daae, to make, that he should prepare for publication an English edition of that professor's tests for colour-blindness, as published in Berlin; also a description of Professor Holmgren's method, with a revised series of the eyesight tests and popular instructions of his own.

32.—This work has been published in a compact form,[1] and its application might even be made a parlour pastime, since it requires no special qualification in the observer, who may indeed be a colour-blind person himself. The Committee hope that this little book may be widely circulated and freely used. This book of tests is in use at Marlborough College, and Mr. Roberts contributes to the Appendix of this report an analysis of the observations made on the whole of the boys and masters, 600 in number, at present in the College, by the Rev. T. A. Preston, a gentleman to whom the Committee are indebted for many valuable contributions to their store of anthropometric observations.

33.—Mr. Roberts has remarked on this important subject that 'some unnecessary alarm will be felt by travellers if they are led to believe that colour-blindness is as prevalent among engine-drivers as other men of their own class, and that one person in every twenty-five is subject to this defect. As a matter of fact, the severer forms of colour-blindness are quickly eliminated from the railway services, either by the conscious inability of the men to distinguish the signals to which they are daily and almost hourly subjected, or by the minor accidents they fall into, which leads their employers to dismiss them as careless, incompetent, or intemperate servants. It is, however, most desirable that this clumsy and

[1] *The Detection of Colour-blindness and Imperfect Eyesight.* By Mr. Charles oberts, F.R.C.S. Published, at 5s., by Mr. Bogue, 3 St. Martin's Place, W.C.

dangerous process of elimination should be superseded by a searching, trustworthy method of testing the colour-sense, especially in fresh candidates for employment on railways and steam-vessels, and it is a disgrace to our country—which was the first to discover and investigate the subject of colour-blindness and to point out its dangers—that it should be the last to recognise its practical importance. But the subject has a much wider bearing than the regulation of traffic by sea and land. As many arts and occupations can only be carried on successfully by persons who possess a normal colour-sense, the testing of the eyesight, whether for colours or objects, should take place in childhood, and before a youth has wasted much time in acquiring technical knowledge which his faulty sight precludes him from using to the same advantage as his more fortunate competitors. Every parent should be cognisant of the condition of the colour-sense of his children, in order that he may provide the colour-blind ones with suitable occupations. Fortunately the art of testing the colour-sense is a very simple one, and is quite within the capacity of a schoolmaster or parent of ordinary intelligence, as it requires neither a knowledge of the theory of colour-blindness (which, indeed, is not yet agreed on by specialists) nor of medicine or surgery.'

34.—Upon the portion of the reference to them which relates to the 'publication of photographs of the typical races of the Empire,' the Committee have not at present anything to add to previous reports. It was intended that a portion of the grant made to the Committee should be applied towards this branch of their work, but the more urgent needs of the general anthropometric work have absorbed the whole of it. Dr. Beddoe, however, has presented a set of photographs of pure Highlanders, and a collection of Irish types has been made by Mr. Park Harrison.

35.—The total expenditure of the Committee during their six years' operations has been only 243*l.* 15*s.*, or about 40*l.* a year. This has included the preparing, printing, and circulating of many thousands of papers of instructions, forms of returns, cards and other publications, and of a costly series of colour-types; besides the judicious payment of small sums, in a few cases, as remuneration to the observers, where their position in life (as regimental sergeants &c.) rendered it desirable; the purchase of photographs and negatives of photographs and of several sets of instruments for making measurements, and the cost of clerical labour in abstracting the returns. The Committee venture to think that they have not improvidently administered the fund at its disposal.

36.—The Committee could, indeed, not have accomplished the work at so small a cost but for the obliging exertions of some of the members, notably Sir Rawson W. Rawson and Mr. Roberts. They have also to acknowledge the services of several gentlemen, not members of the Association, who have kindly consented to act as advisers to the Committee, viz.:—Dr. Bain, Dr. Balfour, Inspector-General Lawson, Dr. Waller Lewis, and Dr. Ogle.

37.—It remains to note briefly the work still to be done by the Committee in the event of their reappointment.

38.—First, it is exceedingly desirable that more complete details should be obtained with regard to the earlier ages from birth to 10 years, a period in which the rate of growth and development is probably more affected by external circumstances than in after-life, and which therefore lends itself more readily to classification.

39.—Secondly, it is of great importance to proceed with the inquiry into anthropometric facts relating to females, which has been commenced with much zeal by the mistresses of some of the high schools for girls, and which by their example may be extended among the various classes of girls' schools throughout the kingdom.

40.—Thirdly, a larger number of statistics are required of individuals belonging to class V.—town industrial workers—to form an average for comparison with the other classes.

41.—Fourthly, further observations should be obtained on the colour sense and on eyesight.

42.—Fifthly, the materials already existing should be more completely worked out, especially those referring to the colour of hair and eyes, as well as the physical proportions of the population in different geographical districts, or districts inhabited by persons of different racial origin.

43.—Lastly, the encouragement in public and private schools and establishments of systematic weighing and measuring on fixed principles should be continued.

44.—The Committee have, in conclusion, to state that the assistant-secretary, Mr. J. Henry Young, has performed his duties with marked intelligence and zeal.

APPENDIX.

Mr. C. Roberts, *who has prepared the Tables from I. to VII. for the Committee, has contributed the following explanations and remarks:—*

Tables I. (height), II. (weight), III. (chest-girth), and IV. (strength), are intended to show the chief physical characters of the British *race*: hence the whole number of observations are given to show the range or variation of the stature, weight, &c., at each age, and the relative number of individuals at each height, weight, &c.; the *mean* height, chest-girth, weight, and strength being indicated by the horizontal lines crossing the columns of figures where the largest number of observations occur.

Tables V. and VI. show the *average* stature and weight of different classes of the nation,—classes which have been differentiated by social or sanitary surroundings and peculiar occupations.

It is necessary to call attention to the difference between the average and the mean as employed in these tables. An *average* is obtained by dividing the sum of the values observed by the number of observations, while the *mean* is the value at which the largest number of observations occur ('the value of greatest frequency.') An average is influenced by exceptional cases, but a mean disregards exceptional cases and is entirely dependent on the predominating numbers; hence I have employed the *mean* to distinguish the racial type, and the *average* the variations to which the race is subject by the modifying influences of local and exceptional causes. To determine the racial type of a nation by means of an *average* it would be necessary to have all classes of the community represented in their due proportions; but the unequal distribution of occupations renders this impossible, unless a general census were taken. Even within narrow limits it is almost impossible to obtain observations of all the individuals of a class, as the taller and better-developed members readily submit to measurement, while the shorter and imperfectly-developed evade examination, and the sick and deformed are passed over altogether. On the other hand, the determination of the racial type by the *mean* is free from these sources of error, as we disregard both the ill-developed and the over-developed individuals, and depend entirely on those which represent the medium development of the class or nation. Table VII., giving the stature of adult men of different classes of the British population shows the difference between the *average* and the *mean*. In those classes, where all the individuals have been accessible and no selection has been attempted, the average and the mean stature are almost identical; but in the case of the recruits for the army, where all the men below a certain standard are excluded, the *average* is an inch higher than the *mean* stature. The *average* in this case implies that recruits are of the same type as the agricultural classes (Class III.), but the *mean* shows that they are really of the type of the town artisan class (Class IV.) from which we know they are chiefly drawn. This also explains why the *average* stature of the general population (Table V.) is half an inch higher than the *mean* stature (Table I.)

The tables show some new and interesting facts in connection with the physical development of the body at different periods of life. Below the age of ten years the observations are very imperfect, but from that age up to sixty years they are very numerous, and fairly representative of all classes of the population.

The accompanying chart (Pl. III.) shows graphically the variations in the *mean* height, chest-girth, weight, and strength of the general population with advancing age, and the relation of these qualities to each other; and the following figures show their actual value:—

Relative Increase in the Size, Weight, and Strength of the Body from 5 to 70 years of age.

Age	Height	Girth	Weight	Strength (drawing power)
	inches	inches	lbs.	lbs.
5	—	No observations at these ages	ditto	ditto
6	2·0			
7	2·0			
8	2·0			
9	2·0			
10	2·0	—	—	—
11	2·0	·5	5·0	—
12	2·0	·5	7·5	2·5
13	2·5	·5	7·5	2·5
14	2·5	1·0	7·5	2·5
15	2·0	1·0	10·0	5·0
16	2·0	2·0	15·0	7·5
17	1·5	2·0	17·5	7·5
18	1·0	·5	7·5	5·0
19	·5	·5	—	2·5
20	—	—	2·5	2·5
21	·5	·5	—	2·5
22	—	—	2·5	2·5
23	—	·5	—	—
24	—	—	2·5	—
25–30	—	·5	—	2·5
30–40	—	—	2·5	−2·5 (decrease)
40–50	—	·5	2·5	−2·5 (decrease)
50–60	·5	No observations at these ages.	2·5	−5·0 (decrease)
60–70	—		2·5	—
70–	—		2·5	—

1. After the age of 10 years the greatest increase in stature takes place at 13 and 14; in chest-girth at 16 and 17; in weight at 15, 16, and 17; and in strength at 15, 16, 17, and 18 years. The chest-girth and the strength have a more direct relation to the weight than to the stature.

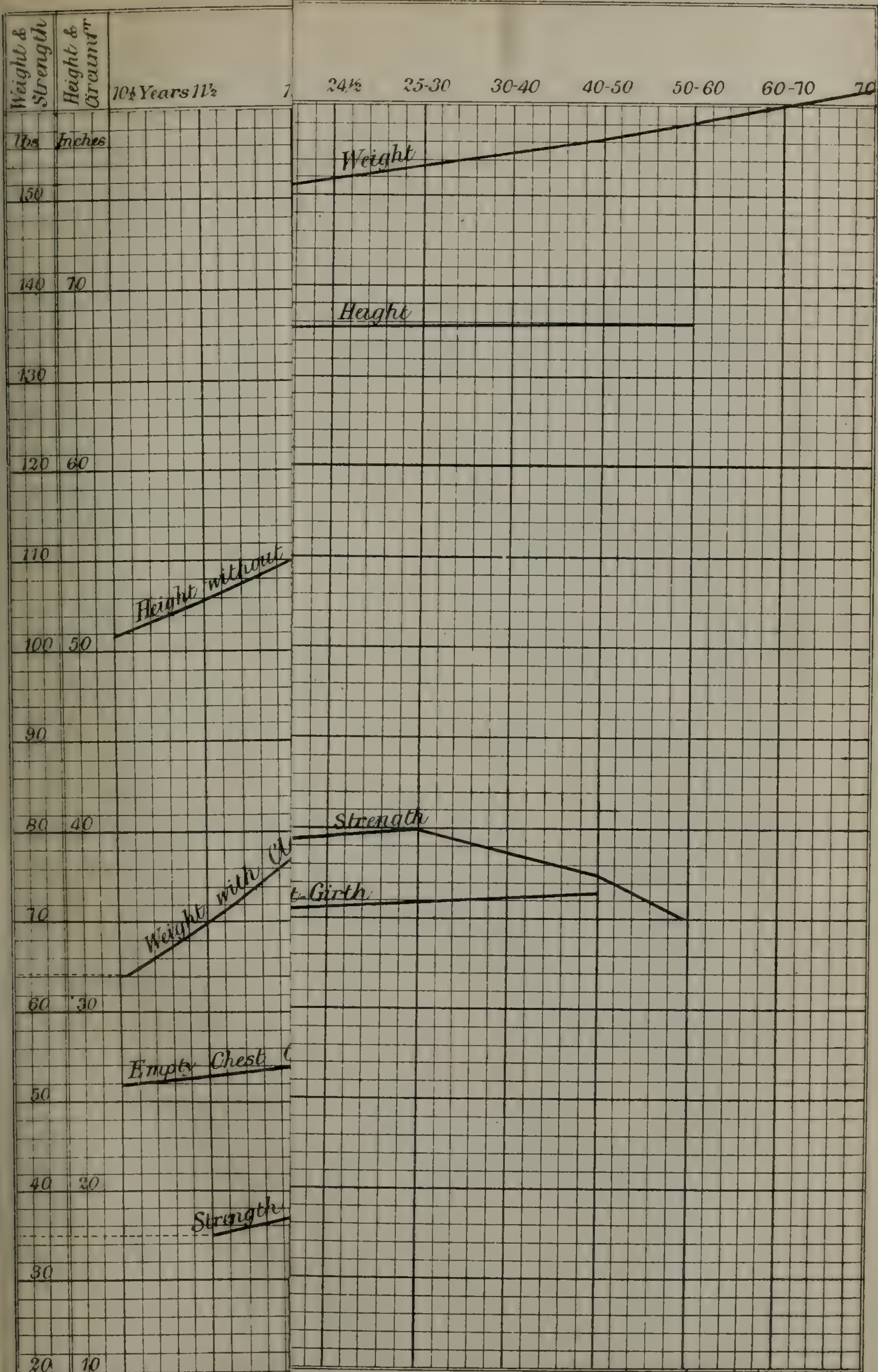
2. The stature increases rapidly to the age of 21, after which there is a very slow, but decided increase, in all classes (see Table V.), up to the age of 70 years.

3. The weight increases rapidly up to the age of 19, after which it continues to increase slowly but uniformly up to the age of 70 years.

4. The chest-girth increases at a rate similar to that of the weight up to the age of 50 years (the limit of the Committee's observations).

5. The strength increases rapidly and at a rate similar to that of the weight up to the age of 19, more slowly and regularly up to 30, after which it declines at an increasing rate to the age of 60 years.

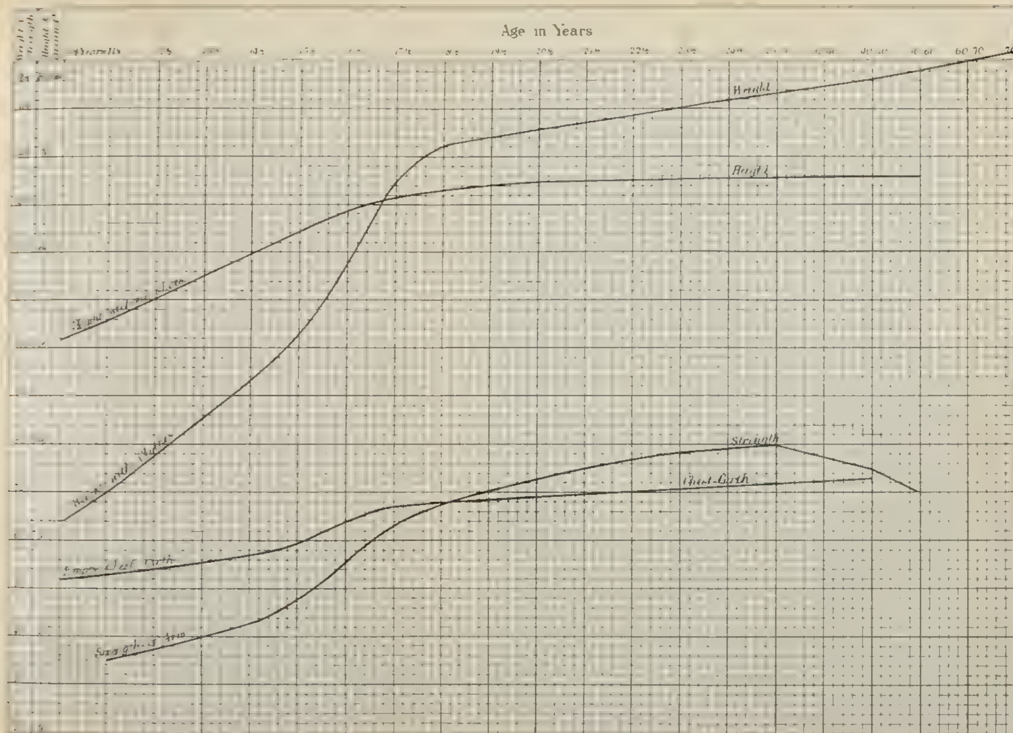
Chart showin at Britian given in Tables I,II,III and IV.



C. Roberts

Spottiswoode & C.o Lith London.

Chart showing the mean Heights, Chest-Girths, Weights, and Strength of the general population of Great Britain given in Tables I, II, III and IV



Illustrating the Report of the Anthropometric Committee

Spottiswoode & C° Lith London

The increase of stature throughout life as shown by Tables I. and V. is a new and unexpected fact, but it is obviously due to the survival of the taller and better developed members of the population, and the elimination by disease or death of the smaller and feebler ones. Quetelet has stated that man attains his maximum height at the age of 30 years and maintains it up to 50 years, after which it begins to recede, and at 90 it has lost three inches. This may be true of individuals if measured from year to year, but it does not appear to be true of the population in the aggregate. The loss of stature resulting from the degeneration and loss of tissues, and the stooping position assumed by old people, is more than counterbalanced by the survival of a greater number of individuals who are above the average in height. The uniform increase in the weight and chest-girth throughout adult life also confirms this view.

The Tables do not show distinctly at what period man attains his full stature, and much difference of opinion exists on this subject. Some French writers (Barnard, Allaire, &c.) maintain that growth in height goes on until the 32nd or 35th year, and Dr. Baxter arrives at the same conclusion from the statistics of the United States Army; while most English writers (Danson, Aitken, Roberts, &c.) regard the 25th as the year of mature growth, and Dr. Beddoe places it as early at the 23rd year, admitting, however, that a slight increase may take place after this age. The difference of opinion on this subject arises, no doubt, from the faulty method of relying on the measurements of many different individuals, instead of measuring the same individuals from year to year until growth ceases. The elimination of the weak and ill-developed by death, the difficulty of following the same class, and all the members of the class, through successive years, and the selection of special classes (*i.e.* recruits, whose ages are never certain), invalidate all conclusions as to the period of maturity, drawn from statistics of measurements of many different persons; but, allowing for these sources of error and judging by the run of the curves formed by the means and averages in Tables I. and V., it is probable that little actual growth takes place after the age of 21, and that it entirely ceases by the 25th year. It is evident, moreover, from Table V., that the full stature is attained earlier in the well-fed and most favoured class (Class I.) than in the ill-fed and least favoured classes of the community.

TABLE I.—Showing the STATURE (without shoes)

Whole number of Observations. The horizontal

Height		Age last											
		5–	6–	7–	8–	9–	10–	11–	12–	13–	14–	15–	16–
ft. in.	in.												
6 5	77 to 78	—	—	—	—	—	—	—	—	—	—	—	—
6 4	76–	—	—	—	—	—	—	—	—	—	—	—	—
6 3	75–	—	—	—	—	—	—	—	—	—	—	1	—
6 2	74–	—	—	—	—	—	—	—	—	—	—	—	2
6 1	73–	—	—	—	—	—	—	—	—	—	—	1	—
6 0	72–	—	—	—	—	—	—	—	—	—	1	2	19
5 11	71–	—	—	—	—	—	—	—	—	1	2	5	19
5 10	70–	—	—	—	—	—	—	—	—	—	4	17	57
5 9	69–	—	—	—	—	—	—	—	1	—	13	33	102
5 8	68–	—	—	—	—	—	—	—	—	2	16	48	160
5 7	67–	—	—	—	—	—	—	1	—	6	32	120	235
5 6	66–	—	—	—	—	—	—	—	—	7	60	168	240
5 5	65–	—	—	—	—	—	—	—	—	13	112	223	293
5 4	64–	—	—	—	—	—	—	—	2	28	136	332	389
5 3	63–	—	—	—	—	—	—	—	6	47	192	353	336
5 2	62–	—	—	—	—	—	—	1	12	85	256	495	278
5 1	61–	—	—	—	—	—	—	1	28	131	378	461	229
5 0	60–	—	—	—	—	—	—	10	55	205	399	405	168
4 11	59–	—	—	—	—	1	—	13	86	279	465	317	109
4 10	58–	—	—	—	—	—	5	38	150	305	514	242	72
4 9	57–	—	—	—	—	2	15	80	206	402	351	127	48
4 8	56–	—	—	—	—	3	31	104	276	373	239	72	20
4 7	55–	—	—	—	—	8	73	210	314	371	138	38	4
4 6	54–	—	—	—	1	23	111	296	295	246	58	20	3
4 5	53–	—	—	—	4	43	203	294	279	116	33	10	1
4 4	52–	—	—	—	5	107	296	321	278	66	16	2	2
4 3	51–	—	—	—	31	167	316	267	138	37	9	2	—
4 2	50–	—	—	2	60	245	300	228	107	11	3	—	—
4 1	49–	—	1	11	133	270	254	136	34	8	2	1	—
4 0	48–	—	2	36	189	299	177	56	26	3	—	—	—
3 11	47–	—	6	67	242	221	94	35	9	—	—	—	—
3 10	46–	—	19	128	247	160	45	15	2	—	—	—	—
3 9	45–	2	25	142	186	67	24	1	1	—	—	—	—
3 8	44–	7	50	173	129	24	4	—	—	—	—	—	—
3 7	43–	17	68	105	56	13	3	—	1	—	—	—	—
3 6	42–	24	69	76	25	1	1	—	—	—	—	—	—
3 5	41–	48	56	32	8	2	—	—	—	—	—	—	—
3 4	40–	32	18	10	5	—	—	—	—	—	—	—	—
3 3	39–	29	10	—	1	—	—	—	—	—	—	—	—
3 2	38–	10	2	1	—	—	—	—	—	—	—	—	—
From 3 – 1	37–38	5	2	1	—	—	—	—	—		—	—	—
Total		174	328	784	1322	1656	1952	2107	2306	2742	3429	3495	2786
Mean Height . . .		41·0	43·0	45·0	47·0	49·0	51·0	53·0	55·0	57·5	60·0	62·0	64·0
Increase		—	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·50	2.50	2·00	2·00

of the General Population of Great Britain.

black lines show the *mean* stature for each age.

Birthday														Centimètres
17–	18–	19–	20–	21–	22–	23–	24–	25–30	30–40	40–50	50–60	60–70	70–	
—	—	—	—	—	—	—	—	—	—	2	—	—	—	195·5–
—	1	1	—	1	1	1	—	1	1	1	—	—	—	193·0–
2	2	—	2	3	1	3	—	1	4	5	—	—	1	190·5–
4	3	1	3	3	2	2	1	9	8	3	4	—	—	187·9–
2	7	10	6	16	11	12	5	26	14	19	4	2	—	185·4–
11	32	24	14	26	15	10	18	55	46	28	4	1	2	182·8–
51	60	52	42	42	43	25	24	88	84	44	22	2	1	180·3–
131	134	83	53	97	57	49	37	152	127	100	15	1	2	177·8–
200	235	128	85	93	82	63	55	213	249	155	26	5	2	175·2–
254	282	186	112	107	90	95	78	245	297	158	**33**	**5**	**1**	172·7–
347	329	**232**	**129**	**109**	**96**	**105**	**101**	**321**	**332**	**196**	33	6	1	170·1–
355	**312**	203	130	140	96	98	81	288	360	203	28	9	1	167·6–
372	319	183	121	95	73	81	68	243	241	157	19	5	—	165·1–
320	221	161	99	54	46	78	61	153	180	103	12	1	1	162·5–
283	195	104	63	23	29	18	42	74	105	54	11	2	—	160·0–
203	132	61	34	11	9	13	24	39	60	35	8	1	—	157·4–
118	47	23	19	3	1	4	2	15	22	17	4	1	—	154·9–
62	15	9	—	1	—	—	5	4	13	9	2	—	—	152·4–
19	5	1	1	—	—	1	—	6	5	4	—	—	—	149·8–
17	3	—	—	—	—	—	—	1	4	—	—	—	—	147·3–
7	—	1	2	—	—	—	—	1	—	—	—	—	—	144·7–
3	—	—	—	—	—	—	—	—	—	—	—	—	—	142·2–
3	—	—	—	—	—	—	—	—	—	—	—	—	—	139·7–
—	2	—	—	—	—	—	—	—	—	—	—	—	—	137·1–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	134·6–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	132·0–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	129·5–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	127·0–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	124·4–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	121·9–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	119·4–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	116·9–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	114·3–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	111·7–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	109·2–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	106·6–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	104·1–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	101·6–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	99·0–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	96·5–
—	—	—	—	—	—	—	—	—	—	—	—	—	—	93·9–
2764	2336	1463	915	824	652	658	602	1935	2152	1293	225	41	12	38953
65·5	66·5	67·0	67·25	67·5	67·5	67·5	67·5	67·5	67·5	67·5	68·0	68·0	—	—
1·50	1·00	·50	·25	·25	—	—	—	—	—	—	·50	—	—	—

TABLE II.—Showing the WEIGHT (with clothes) of the general population of Great Britain.
Whole number of observations. The horizontal black lines show the *mean* weight at each age.

Weight lbs.	Age last Birthday 10–	11–	12–	13–	14–	15–	16–	17–	18–	19–	20–	21–	22–	23–	24–	25–30	30–40	40–50	50–60	60–70	70–	Kilo-grammes
259–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	3	2	—	—	117·6–
245–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	5	—	—	—	111·2–
231–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10	5	2	2	2	104·9–
217–	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	2	16	15	7	—	—	98·5–
203–	—	—	—	—	—	—	—	—	4	2	—	2	—	2	1	10	30	32	15	4	—	92·2–
189–	—	—	—	—	—	—	—	8	16	8	3	9	6	7	10	41	89	75	14	2	3	85·8–
175–	—	—	—	—	—	1	4	23	53	37	34	41	18	32	20	122	318	180	26	3	—	79·4–
170–	—	—	—	—	—	1	5	48	72	60	32	67	28	22	21	86	121	91	14	4	1	76·3–
165–	—	—	—	—	—	1	5	31	46	32	29	36	52	29	17	118	159	90	17	1	1	74·9–
160–	—	—	—	—	1	4	15	96	130	83	75	87	35	46	45	152	206	115	21	3	1	72·6–
155–	—	—	—	—	1	2	20	132	159	99	85	102	67	49	54	148	191	123	12	5	—	70·4–
150–	—	—	—	—	1	6	34	168	217	159	95	169	80	73	71	197	208	110	12	2	—	68·1–
145–	—	—	—	—	2	17	76	243	256	168	109	177	95	72	73	176	210	118	13	1	1	65·8–
140–	—	—	—	1	4	27	110	255	287	197	125	188	88	90	53	219	205	109	14	4	2	63·6–
135–	—	—	—	—	11	53	129	277	260	186	98	165	72	48	44	128	110	60	8	—	—	61·3–
130–	—	—	—	1	22	71	190	264	197	164	63	135	72	47	38	117	96	58	7	3	—	59·0–
125–	—	—	—	7	42	112	222	278	184	95	66	78	55	40	33	71	58	34	4	1	1	56·7–
120–	—	—	—	7	58	153	234	235	128	73	33	42	31	19	15	34	51	22	2	2	—	54·5–
115–	—	—	2	12	74	240	279	168	75	43	18	24	16	10	17	35	25	15	4	—	—	52·2–
110–	—	—	1	24	136	299	203	112	57	34	13	11	8	5	6	13	24	9	4	—	—	49·9–
105–	—	—	9	42	149	330	250	87	17	19	2	9	1	2	2	5	6	4	1	—	—	47·7–
100–	—	3	17	82	226	340	173	45	12	7	2	—	1	1	—	5	3	1	—	—	—	45·4–
95–	—	8	29	146	340	404	124	26	4	2	—	1	—	—	—	—	—	—	—	—	—	43·1–
90–	1	11	58	195	352	363	90	9	1	1	1	—	—	—	—	—	—	—	—	—	—	40·9–
85–	2	22	81	278	423	287	48	10	2	—	—	—	—	—	—	—	—	—	—	—	—	38·6–
80–	17	62	126	299	307	178	21	1	3	—	—	—	—	—	—	—	—	—	—	—	—	36·3–
75–	39	86	133	269	210	81	7	1	—	—	—	—	—	—	—	—	—	—	—	—	—	34·0–
70–	64	120	129	134	66	33	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	31·8–
65–	60	104	97	76	20	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	29·5–
60–	50	104	81	27	12	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	27·2–
55–	59	45	13	14	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	25·0–
50–	11	11	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	22·8–
45–	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	20·5–
From 40–45	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18·2–
Total . .	303	578	779	1614	2459	3012	2240	2517	2180	1469	883	1343	725	595	520	1679	2142	1274	199	37	12	26560
Mean . .	65·0	70·0	77·5	85·0	92·5	102·5	117·5	135·0	142·5	143·7	145·0	146·2	147·5	148·7	150·0	151·2	152·5	155·0	157·5	160·0	162·5	—
Increase .	—	5·0	7·5	7·5	7·5	10·0	15·0	17·5	7·5	1·2	1·3	1·2	1·3	1·2	1·3	1·2	1·3	2·5	2·5	2·5	2·5	—

TABLE III.—Showing the *empty* CHEST-GIRTH of the General Population of Great Britain.

Whole Number of Observations. The horizontal black lines show the *mean* Chest-girth at each age.

Chest-girth in Inches	Age last Birthday																		Centi-mètres
	10–	11–	12–	13–	14–	15–	16–	17–	18–	19–	20–	21–	22–	23–	24–	25–30	30–40	40–50	
45 to 46	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1	1	114·3–
44–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	4	2	111·7–
43–	—	—	—	—	—	—	—	—	—	—	—	1	—	1	1	4	7	7	109·2–
42–	—	—	—	—	—	—	—	—	1	—	—	1	1	4	2	2	25	24	106·6–
41–	—	—	—	—	—	—	—	—	2	2	1	3	1	3	4	27	33	10	104·1–
40–	—	—	—	—	—	—	—	3	2	7	10	5	5		9	29	60	27	101·6–
39–	—	—	—	—	—	—	—	11	20	15	16	15	13	16	15	63	97	25	99·0–
38–	—	—	—	—	—	—	8	31	50	41	38	40	36	35	34	102	119	40	96·5–
37–	—	—	—	—	2	—	12	71	123	78	78	82	70	52	50	139	144	57	93·9–
36–	—	—	—	—	—	2	29	164	204	191	161	158	100	73	86	190	177	62	91·4–
35–	—	—	—	—	3	15	39	234	354	332	202	176	136	105	89	160	154	44	88·9–
34–	—	—	—	1	5	29	103	363	552	446	270	207	135	103	97	179	116	46	86·3–
33–	—	—	—	1	10	59	181	424	528	353	173	102	87	37	43	103	57	9	83·8–
32–	—	—	—	2	16	152	199	357	324	180	73	52	43	30	18	38	24	7	81·2–
31–	—	1	1	21	62	210	184	212	157	89	32	24	17	8	5	19	7	1	78·7–
30–	—	2	7	48	94	334	162	104	73	39	15	8	3	9	7	15	2	—	76·2–
29–	1	17	45	86	162	269	103	58	31	15	8	4	4	—	—	4	1	—	73·6–
28–	23	50	76	137	160	277	179	21	12	4	1	4	—	1	—	—	—	—	71·1–
27–	31	65	134	152	158	202	45	14	4	1	—	1	—	—	—	—	1	—	68·5–
26–	62	101	106	86	135	122	24	4	2	—	1	2	—	—	—	—	—	—	66·0–
25–	57	92	62	39	64	41	7	1	—	—	—	—	—	—	—	—	—	—	63·5–
24–	39	34	19	16	18	11	2	1	—	—	—	—	—	—	—	—	—	—	60·9–
23–	5	12	4	6	4	2	—	—	1	1	—	—	—	—	—	—	—	—	58·4–
22–	3	4	2	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	55·8–
From 21–22	1	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	53·3–
Total . .	222	379	458	596	894	1725	1280	2073	2440	1794	1079	885	651	479	460	1077	1029	362	17883
Mean . .	26·00	26·50	27·00	27·50	28·50	29·50	31·50	33·50	34·00	34·50	34·75	35·00	35·25	35·50	35·75	36·00	36·25	36·50	—
Increase .	—	·50	·50	·50	1·00	1·00	2·00	2·00	·50	·50	·25	·25	·25	·25	·25	·25	·25	·25	—

TABLE IV.—Showing the STRENGTH (drawing power) of the General Population of Great Britain.

Whole number of Observations. The horizontal black lines show the *mean* Strength at each age.

Drawing Strength. lbs.	Age last Birthday 1–	12–	13–	14–	15–	16–	17–	18–	19–	20–	21–	22–	23–	24–	25–30	30–40	40–50	50–60	Kilo-grammes
155–160	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	70·4–
150–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	68·1–
145–	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	1	—	65·8–
140–	—	—	—	—	—	—	1	—	1	—	—	—	1	—	1	—	—	—	63·6–
135–	—	—	—	—	—	—	1	2	1	—	—	1	—	—	—	—	—	—	61·3–
130–	—	—	—	—	—	—	—	1	1	—	1	1	—	—	2	—	—	—	59·0–
125–	—	—	—	—	1	—	1	1	—	—	—	—	—	—	2	3	1	—	56·7–
120–	—	—	—	—	1	—	3	1	6	4	1	1	1	2	5	1	—	—	54·5–
115–	—	—	—	—	—	1	1	4	2	2	1	2	—	—	—	6	—	—	52·2–
110–	—	—	—	—	—	—	3	3	5	4	4	3	1	2	6	3	—	1	49·9–
105–	—	—	—	1	—	—	4	7	13	6	1	3	3	2	14	6	3	1	47·7–
100–	—	—	—	1	2	4	—	14	7	3	10	6	6	5	26	5	3	—	45·4–
95–	—	—	—	1	1	3	8	19	15	15	15	17	11	6	41	21	2	2	43·1–
90–	—	—	—	1	3	1	12	20	16	22	18	19	23	13	61	39	9	2	40·9–
85–	—	—	—	1	1	7	10	19	27	18	20	20	14	18	74	57	14	1	38·6–
80–	—	—	1	1	6	16	17	36	43	30	30	26	29	23	89	56	22	2	36·3–
75–	—	—	1	3	13	14	26	42	30	34	27	26	35	23	96	97	22	4	34·0–
70–	—	—	—	7	18	35	51	52	48	32	30	38	33	30	89	68	29	6	31·8–
65–	—	—	2	9	20	35	49	54	61	32	24	21	17	19	32	93	8	5	29·5–
60–	—	—	3	24	48	60	53	60	54	32	21	15	9	13	28	29	12	6	27·2–
55–	—	—	5	19	57	62	51	45	34	18	9	1	6	1	7	28	8	3	25·0–
50–	1	3	15	51	102	70	59	25	11	4	1	2	—	2	3	9	5	1	22·8–
45–	3	5	16	63	89	62	25	8	5	3	—	—	1	—	—	7	2	—	20·5–
40–	5	14	36	74	104	39	10	2	1	—	—	—	1	—	—	2	2	—	18·2–
35–	8	9	25	68	50	21	2	—	—	—	—	—	—	—	—	2	1	—	15·9–
30–	6	15	12	47	14	8	1	—	—	—	—	—	—	—	—	—	—	—	13·7–
25–	4	3	3	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	11·4–
From 20 to 25	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9·1–
Total . .	27	49	119	375	531	438	388	415	382	259	213	202	192	159	578	534	144	34	5,039
Mean Strength	35·0	37·5	40·0	42 5	47·5	55·0	62·5	67·5	70·0	72·5	75·0	77·5	77·5	77·5	80·0	77·5	75·0	70·0	—
Increase .	—	2·5	2·5	2·5	5·0	7·5	7·5	5·0	2·5	2·5	2·5	2·5	—	—	2·5	—	—	—	—

NOTE.—See Diagram on next page showing the manner in which observations relating to strength are taken.

The following is a copy of the drawing and instructions issued by the Committee to observers in collecting statistics of strength:—

The above figure represents the position in which the strength of arm should be tested. The right or left arm, whichever is the stronger, should be used to draw, and the other to resist. The resisting arm must be free, and extended straight from the side, as nearly as possible in the line of the shoulders, and the hand of the other arm brought back towards the ear, as an archer uses a bow.

TABLE V.—Showing the average STATURE (*without shoes*) of different classes of the Population of Great Britain.

Age last Birth-day	General Population. All Classes. Town and Country			Class I. Professional Classes. Town and Country			Class II. Commercial Classes. Towns			Class III. Labouring Classes. Country			Class IV. Artisans Towns		
	No. Obs.	Average Height. Inches	Increase. Inches	No. Obs.	Average Height. Inches	Increase. Inches	No. Obs.	Average Height. Inches	Increase. Inches	No. Obs.	Average Height. Inches	Increase. Inches	No. Obs.	Average Height. Inches	Increase. Inches
Birth	—	—	—	—	—	—	—	—	—	—	—	—	100	19·34	—
1–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4–	—	—	—	—	—	—	—	—	—	—	—	—	21	38·45	—
5–	—	—	—	—	—	—	—	—	—	—	—	—	37	41·09	2·64
6–	—	—	—	—	—	—	—	—	—	—	—	—	40	43·28	2·19
7–	—	—	—	—	—	—	3	46·16	—	—	—	—	53	45·71	2·43
8–	—	—	—	—	—	—	16	47·31	1·15	268	47·03	—	176	47·06	1·35
9–	—	—	—	—	—	—	81	50·18	2·87	418	49·06	2·03	358	48·94	1·88
10–	1551	51·84	—	101	53·69	—	331	52·04	1·86	783	50·93	1·87	336	50·72	1·78
11–	1766	53·50	1·66	242	55·23	1·54	687	53·76	1·72	597	52·32	1·39	240	52·68	1·96
12–	1981	54·99	1·49	490	57·29	2·06	902	55·29	1·53	395	53·67	1·35	194	53·72	1·04
13–	2743	56·91	1·92	869	59·08	1·79	857	57·43	2·14	403	55·31	1·64	614	55·81	2·09
14–	3428	59·33	2·42	966	61·29	2·21	800	59·47	2·04	9	57·94	2·63	1653	58·61	2·80
15–	3507	62·24	2·91	974	63·61	2·32	544	62·19	2·72	515	61·82	3·88	1465	61·36	2·75
16–	2780	64·31	2·07	1102	66·23	2·62	110	64·55	2·36	177	63·62	1·80	1391	62·85	1·49
17–	2745	66·24	1·93	1852	67·81	1·58	107	66·59	2·04	75	65·87	2·25	711	64·70	1·85
18–	2305	66·96	·73	1724	68·26	·45	62	67·44	·85	148	66·53	·66	371	65·60	·90
19–	1435	67·29	·33	951	68·58	·32	63	67·55	·11	143	66·87	·34	277	66·17	·57
20–	880	67·52	·23	461	69·08	—	61	67·58	·03	183	66·93	·06	175	66·50	·33
21–	757	67·63	·11	364	68·70	·12	51	67·79	·21	177	67·15	·22	165	66·55	·05
22–	558	67·68	·05	227	68·94	—	53	67·82	·03	169	67·35	·20	109	66·60	·05
23–	592	67·48	—	114	68·73	·03	59	67·42	—	274	67·38	·03	145	66·40	—
24–	517	67·73	·05	57	68·82	·09	62	68·09	·27	258	67·47	·09	140	66·55	—
25–							47	67·93	—	218	67·52	·05	92	66·40	—
26–							47	68·07	—	194	67·46	—	74	66·46	—
27–	1794	67·80	·07	107	69·14	·32	27	68·13	·04	162	67·76	·21	66	66·67	·07
28–							33	67·65	—	208	67·31	—	59	66·65	—
29–							26	67·96	—	163	67·54	—	53	66·82	·15
30–35	1886	68·00	·20	52	69·61	·37	85	67·70	—	745	67·59	—	180	66·65	—
35–40							82	68·07	—	631	67·62	—	111	67·0[illegible]	·26
40–50	1148	67·96	—	46	69·38	—	79	68·09	—	943	67·56	—	80	66·80	—
50–60	198	67·92	—	13	69·50	—	16	67·69	—	147	68·06	·30	22	66·45	—
60–70	44	67·41	—	5	69·10	—	3	66·16	—	34	67·88	—	2	66·50	—
70–	12	69·22	—	—	—	—	1	68·50	—	11	69·95	—	—	—	—
Total Obs.	31627	—	—	10717	—	—	5195	—	—	8448	—	—	9410	—	—

TABLE VI.—Showing the average WEIGHT (*including clothes*) of different classes of the Population of Great Britain.

Age last Birth-day	General Population. All Classes. Town and Country			Class I. Professional Classes. Town and Country			Class II. Commercial Classes. Towns			Class III. Labouring Classes. Country			Class IV. Artisans. Towns		
	No. Obs.	Average Weight. Lbs.	Increase. Lbs.	No. Obs.	Average Weight. Lbs.	Increase. Lbs.	No. Obs.	Average Weight. Lbs.	Increase. Lbs.	No. Obs.	Average Weight. Lbs.	Increase. Lbs.	No. Obs.	Average Weight. Lbs.	Increase. Lbs.
Birth	—	—	—	—	—	—	—	—	—	—	—	—	100	7·5	—
1–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8–	—	—	—	—	—	—	—	—	—	238	55·3	—	115	53·7	—
9–	—	—	—	—	—	—	81	60·3	—	345	61·2	5·9	296	58·3	4·6
10–	1464	67·5	—	92	74·0	—	370	65·2	4·9	721	67·0	5·8	281	64·0	5·7
11–	1599	72 0	4·5	185	78·7	4·7	686	68·0	2·8	553	72·2	5·2	175	69·0	5·0
12–	1786	76·7	4·7	369	84·9	6·2	905	73·2	5·2	366	75·9	3·7	146	73·0	4·0
13–	2443	82·6	5·9	621	91·6	6·7	854	80·1	6·9	328	79·7	3·8	640	79·0	6·0
14–	2952	92·0	9·4	748	102·2	10·6	799	89·5	9·4	9	89·2	9·5	1396	87·3	8·3
15–	3118	102·7	10·7	652	114·3	12·1	344	99·4	9·9	676	100·6	11·4	1446	96·4	9·1
16–	2235	119·0	16·3	834	129·5	15·2	55	117·2	17·8	169	117·2	16·6	1177	112·2	15·8
17–	2496	130·9	11·9	1705	141·7	12·2	38	128·8	11·6	80	131·5	14·3	673	121·5	9·3
18–	2150	137·4	6·5	1638	146·4	4·7	39	135·1	6·3	135	138·7	7·2	338	129·3	7·8
19–	1438	139·6	2·2	940	148·5	2·1	69	138·6	3·5	140	140·2	1·5	289	131·1	1·8
20–	851	143·3	3·7	451	152·4	3·9	52	140·1	1·5	175	144·3	4·1	173	136·4	5·3
21–	738	145·2	1·9	365	152·7	·3	52	143·9	3·8	164	147·8	3·5	157	136·2	—
22–	542	146·9	1·7	215	152·8	·1	51	145·5	1·6	167	150·6	2·8	109	138·6	2·2
23–	551	147·8	·9	112	151·5	—	57	146·8	1·3	279	152·8	2·2	103	140·2	1·6
24–	483	148·0	·2	56	149·6	—	57	147·1	·3	250	151·9	—	120	143·4	3·2
25–							45	148·5	1·4	224	154·1	1·3	61	139·9	—
26–							46	154·1	5·6	192	154·1	—	58	142·2	—
27–	1559	152·3	4·3	115	156·3	3·5	26	149·2	—	171	156·7	2·6	56	146·9	6·5
28–							33	156·1	2·0	213	155·1	—	50	148·0	1·1
29–							26	154·3	—	161	158·0	1·3	46	148·1	·1
30–35	964	159·8	7·5	24	171·5	15·2	87	158·5	2·4	700	159·2	1·2	153	150·1	2·0
35–40	840	164·3	4·5	24	173·5	—	80	166·6	8·1	631	160·5	1·3	105	156·5	6·4
40–50	1040	163·3	—	44	172·5	1·0	72	168·6	2·0	911	162·0	1·5	113	151·7	—
50–60	179	166·1	1·8	13	174·5	2·0	16	173·4	4·8	129	170·9	8·9	21	145·6	—
60–70	35	158·1	2·0	5	164·5	—	3	165·7	—	24	170·9	—	3	130·8	—
70–	12	182·1	—	—	—	—	1	189·0	—	11	175·3	4·4	—	—	—
Total Obs.	29475	—	—	9208	—	—	4944	—	—	8162	—	—	8300	—	—

TABLE VII.—Showing the RELATIVE STATURE OF ADULTS of the ages from 25 to 30 years under different physical and social conditions.

The horizontal black lines show the *mean* Height of each class. The averages are given at the bottom of the Table.

Height in inches	General Population all Classes	Metropolitan Police and Fire Brigade	Class I. Professional Classes	Class II. Commercial Classes, Clerks and Shopkeepers	Class III. Labouring Classes, Agriculturl. Miners, Sailors	Class IV. Artisan Classes living in Towns	Class V. Sedentary Occupations: Factories, Shoemakers, Tailors	Class VI.—Special Classes: Recruits for the Army, 1879	Class VI.—Special Classes: Prisoners all Classes	Class VI.—Special Classes: Lunatics, all Classes	Class VI.—Special Classes: Surrey Militia
76 to 77	1	1	—	—	—	—	—	—	—	—	—
75–76	1	—	—	—	1	—	—	—	—	—	—
74–75	9	2	1	—	6	—	—	—	1	—	—
73–74	26	7	3	2	11	2	1	1	2	1	—
72–73	55	16	7	6	24	2	—	—	3	2	—
71–72	88	22	9	8	42	3	4	—	6	6	—
70–71	152	38	21	14	56	14	9	3	20	7	2
69–70	213	37	20	30	103	15	8	8	29	18	8
68–69	245	23	13	25	130	41	13	12	41	20	11
67–68	321	12	16	35	179	57	22	12	73	40	11
66–67	288	6	8	24	144	78	28	14	78	62	13
65–66	243	2	4	19	111	64	43	9	76	51	14
64–65	153	2	2	11	69	38	31	5	78	52	19
63–64	74	—	2	5	38	17	12	—	41	29	16
62–63	39	—	—	1	20	4	14	—	21	29	5
61–62	15	—	1	—	6	5	3	—	17	12	—
60–61	4	—	—	—	1	2	1	—	2	5	—
59–60	6	—	—	—	2	—	4	—	1	4	—
58–59	1	—	—	—	1	—	—	—	1	1	—
57–58	1	—	—	—	1	—	—	—	—	2	—
From 56 to 57	—	—	—	—	—	—	—	—	1	—	—
Total . . .	1935	168	107	180	945	342	193	64	491	341	99
Mean Height.	67·5	70·0	69·0	68·0	67·5	66·5	65·5	66·5	66·0	65·5	64·5
Average . .	67·54	70·04	69·14	67·95	67·51	66·61	65·92	67·44	66·16	65·65	65·94

NOTE—A Table similar to this, but relating to boys of the age of 11-12 years, is published in the Committee's Report for 1880. It will be seen that the same differences exist in both Tables, and that the differentiation of the classes takes place before the age of 11 years, and probably is in a great measure hereditary.

Mr. FRANCIS GALTON *who has prepared the Tables VIII. to X. on the Range in Height, Weight, and Strength, has contributed the following remarks upon them.*

In determining the range I have employed and extended the method by which the so-called 'probable error' is found. That is to say, the observations in each series were arranged in the order of their respective magnitudes, beginning with the lowest and ending with the highest. A definite fraction was then cut off from either end of the series; the values at the exact points where the divisions took place were ascertained by interpolation, and the difference between these gave the range of the intermediate portion.

The fractions so cut off were—(1) a half; this gave simply the median value: (2) a quarter; this gave the upper and lower 'quartile' values, and consequently the 'interquartile' range (which is equal to twice the 'probable error'): (3) a tenth; this gave the upper and lower 'decile' values, and consequently the 'interdecile' range. The following are the definitions of these terms, Median, Quartile, and Decile:—

The *Median*, in height, weight, or any other attribute, is the value which is exceeded by one-half of an infinitely large group, and which the other half falls short of.

The *Upper Quartile* is that which is exceeded by one-fourth part of an infinitely large group, and which the remaining three-fourths fall short of. Conversely for the *Lower Quartile.*

The *Upper Decile* is that which is exceeded by one-tenth of an infinitely large group, and which the remaining nine-tenths fall short of. The *Lower Decile* is the converse of this; one-tenth falls short of it, and nine-tenths exceed it.

Each line of the annexed tables is to be read as in the following instance, taken from the fourth line of Table VIII*a*.

Example:—869 observations were made of boys of the professional classes, of 13 years of age, whence it appears that—

(1) There are as many boys above the height of 59·0 inches as below it. This Median value differs from the Average value by 0·1 inch, which shows a trifling want of symmetry in the distribution of the heights.

(2) One-fourth of the boys exceeds the height of 60·9 inches, and another fourth falls short of 57·1 inches; in consequence, the difference of 3·8 inches defines the range in height of the intermediate two-fourths, or middle half, of the boys.

(3) One-tenth of them exceeds 62·8 inches, while another tenth falls short of 55·4 inches. The difference between these numbers is 7·4, which defines the range in height of the intermediate eight-tenths, or three-quarters of the boys.

(4) The highest measurement actually taken in these 869 observations was 71·5 inches (reckoning to the nearest inch), and the lowest was similarly 49·5 inches, showing a difference of 22 inches.

The information as to the extreme values that happen to have been observed in these 869 cases, is avowedly of little solid value. Their magnitude depends to a great degree upon the accident of this particular series happening to include, or not to include, one very exceptional instance of great stature and another of small stature. It is beyond the power of statistical science to determine the extreme values that might possibly be observed.

On the other hand, the Median, Decile, and Quartile values possess a trustworthiness of the same order as that of the Average or Arithmetic Mean values. They are not sensibly affected by a solitary accident, and a moderately large series of observations is sufficient to determine them with as much precision as is needful for ordinary statistical purposes.

A small error in the position of the medians, quartiles, &c., causes an error in their values proportional to the tangent of the circumscribing curve at the corresponding points. On protracting the curves for height, weight, and strength from their tabular values, it appears that the tangents at the quartiles are but little greater than those at the medians, but that the tangents at the deciles are about twice as great. Again, the tangents at corresponding points in two of these curves, drawn from different numbers of observations (the ordinates relating to the successive values being supposed in all cases to stand at the same distances apart), must vary inversely as the number of observations. Consequently, in order to ascertain decile values in the series with which we are now dealing, with the same accuracy as medians and quartiles, we require to have about twice the number of observations.

It appears to be well worth while to print, not only summary tables of results, as Table VIII. for the height, and Table IX. for the weight, but to supplement these by other tables going more into detail and referring to the classes separately. So much has been written on the applicability of the Exponential Law of Error to statistical results, that it is important to publish material for the more complete discussion of the subject. Into the discussion itself, this is hardly the place to enter, further than by saying that the median values will be found to conform very closely indeed with the arithmetical means, that the distribution of variations on either side of the median value is so symmetrical that the difference between either quartile or decile and the median is almost exactly one-half of the difference between the two quartiles or the two deciles, and, lastly, that the range between the two deciles is very commonly a trifle short of double the range between the two quartiles. According to the Exponential Law of Error, the results in every case would have been nearly the same as these.

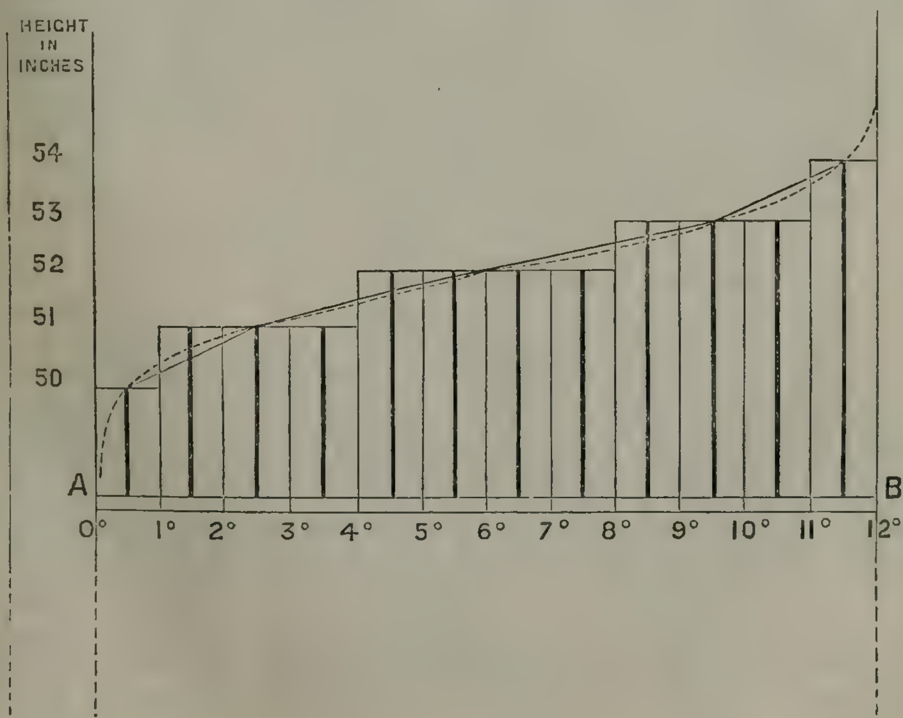
I would refer those who desire to pursue the subject on a theoretical basis to a paper of my own on the 'Geometric Mean in Vital and Social Statistics,' in the Proceedings of the Royal Society, October, 1879, and more especially to the subsequent one by Dr. Donald McAlister on the 'Law of the Geometric Mean,' in which the equation is given to the circumscribing curve, both on the assumption of the arithmetical mean of two fallible observations of the same fact being the most probable inference from them, and on that of the Geometric Mean being accepted, as I have argued that it ought to be, as the more probable inference in all physiological phenomena.

On the Calculation of Deciles, Quartiles, and Medians.

The deciles, quartiles, and medians are ordinates to an ideal curve, supposed to be constructed as follows:—An infinite number of measurements, belonging to the same statistical group, are arranged in the order of their magnitudes, and ordinates of lengths corresponding respectively to each of them are erected side by side, at equal, but infinitesimally small, distances apart, along a given line AB; then the curve passing through their tops is the curve in question. The median is the ordinate corresponding to the abscissa of $\frac{1}{2}$·AB; the lower and upper quartiles correspond respectively to $\frac{1}{4}$·AB and to $\frac{3}{4}$·AB; the lower and upper deciles correspond to $\frac{1}{10}$ AB and to $\frac{9}{10}$ AB. It may be remarked that the general shape of the curve will always resemble that shown in the diagram, owing to the recognised statistical fact that medium values are much more frequent than extreme ones, deviations from the mean value becoming increasingly rare in a rapidly increasing ratio.

In order to deduce approximately the above-mentioned curve from a finite series of n observations, we divide AB into n equal spaces, and erect an ordinate in the middle of each of a length proportionate to the corresponding datum. The spaces will be defined by divisions that run from 0° at A, to n° at B, and therefore there will be $n+1$ of them. The first ordinate will stand at 0°·5 of the graduated scale, the second at 1°·5, and so on, while the abscissæ of the deciles, quartiles, and medians will be at the following positions: $\frac{n}{10}, \frac{n}{4}, \frac{n}{2}, \frac{3n}{4}, \frac{9n}{10}$. The data are grouped and tabulated as in columns A and B of the following example, which, for the sake of simplicity in illustration, consists of only twelve observations.

Height in inches	Number of observations	Total number of previous records	Halves of the entries in column B	Abscissæ. — Sums of the columns C and D
A	B	C	D	E
—	—	12	—	12·0
54	1	11	0·5	11·5
53	3	8	1·5	9·5
52	4	4	2·0	6·0
51	3	1	1·5	2·5
50	1	—	0·5	0·5



To work out this case, take a base line AB, divide it into twelve equal parts, and erect an ordinate (see the dark lines in the diagram) in the middle of each of them. The first ordinate will reach to 50 inches (the lower part of the ordinate is suppressed to save space); the next three will reach to 51 inches; the next four to 52 inches, and so on according to the tabular data. Erect ordinates of suitable heights (see the light lines in the diagram) at each of the graduations, and draw horizontal lines through the top of each group of dark lines until it meets the light lines on either side of them. A figure is thus produced which consists of a series of rectangles rising in equal steps. A curved line (see the dotted line) which smooths off the corners of the rectangles, is the curve upon which the deciles, &c., are to be measured, and the broken line formed by joining the central points of the upper boundary of each rectangle may be adopted as an equivalent to the curve without material error. The ordinates at these central points are those that correspond to the successive integral heights of 50, 51, 52, &c. inches. The value of their corresponding abscissæ is equal to half the number of the dark lines in the rectangle in question *plus* the number of dark lines in all the previous rectangles. An inspection of the figure will show this more readily than a verbal explanation.

The calculation is very easily made by appending to the tabular data in A and B three other columns, C, D, and E. Column C contains in each line the sum of all the heights inferior to the number of inches found in A upon the same line. D contains the halves of the entries in B, and E contains the sum of the entries in C and D, and consequently gives the abscissæ corresponding to the several integral inches.

Example: to find the lower decile in the above instance. As we know the abscissa of the decile, we proceed to find from column E the two entries between which it lies, and we take the corresponding ordinates from A, whence we find the decile itself by simple interpolation. As there are twelve observations in the example, the abscissa of the decile is 1·2, which lies between the tabular entries in E of 0·5 and 2·5, and these are the abscissæ of 50 and 51 inches respectively. Therefore the decile is equal to 50 inches *plus* a certain fraction of an inch, x, whose value may be ascertained by a simple rule of three. Thus:—

difference between 2·5 and 0·5 : 1 inch :: difference between 1·2 and 0·5 : x inches

x=0·35, and the required decile=50·35 inches.

On a first glance at the tables, a very remarkable fact is manifest. It is the uniformity of range at all the ages given in it. Let us begin with height, as shown in Table VIII.; the range between the upper and lower fourths is as great at 11, or even at 8, years of age as it is at 22 or 40 years, and at the intermediate ages it is much the same, viz., about 3·3 inches. It might have been expected that the range would vary with the average height, so that the fact of boys of 11 years of age having a median or average height of 53·5 inches, and an interquartile range of 3·2 inches, would imply that men of 22 years, having a median height of 67·6 inches, would have an interquartile range of 4·4 inches, because 53·5 : 3·2 :: 67·6 : 4·4. The interdecile range is equally constant. It seems so difficult to conceive of variation otherwise than as a fraction of the average height, that we are justified in expressing the steadiness of the range at different ages by the phrase that the variation in height at all ages between boyhood and manhood is inversely proportional to the average height at those ages. The results of 100 measurements of newly-born male infants at their full term, furnished to me by Mr. Roberts, show a large range; the median value is 19·2, the interquartile range is 1·8, and the interdecile range is 3·5; but it must be recollected that it is difficult to measure infants with accuracy.

It would be of much interest to examine this question further, and to find out at what age the range begins to be steady, but my data are at present insufficient to enable me to do this.

As regards weight, much the same holds good at and after the age of 14, but the range decreases steadily as we go further back. Among the newly-born infants the median value is 7·6 lbs., the interquartile range is 1·7 lbs., and the interdecile range is 3·3 lbs.

As regards strength the range is small in early life, large in early manhood, but in after-life other conditions appear which materially and steadily reduce it. The upper quartile values begin to decrease and the lower quartiles to increase; in other words, the stronger quarter of Englishmen do not keep up their full vigour, and the weaker quarter become steadily stronger. This latter event is certainly due in large part to the previous removal of many of the weakest by early death. As regards the deciles we see that the athletes preserve their vigour very fairly, while the weakly tenth considerably improve, so that the interdecile range also decreases in advancing life.

Another very curious fact is a marked increase of range of height from about 14 to 16 years of age in Classes I. and II., and in a less degree in Class IV., which disappears afterwards. Probably the increase of range takes place in different boys at slightly different ages, and therefore becomes smoothed down in the mean result. If so, it would be still more striking if the classes had been further subdivided. I gather from this temporary increase of range that precocity is, on the whole, of no advantage in later life, and that it may be a disadvantage. It is certain that the precocious portion do not maintain their lead to the full extent; it is possible that they may actually fall back, and that many of those who occupied a low place in the statistical series between the ages of 14 and 16 occupy a high place after those years. The full discussion of this requires the collation of many *individual histories*; it cannot be effected through mean results. Perhaps the class of statistical researches in anthropometry that most deserves encouragement at the present time is the preservation of these records of the same individual throughout life. He might with little trouble be measured and weighed annually or more often, in the nursery, at school, at college, and in after-life, and all the records might be kept *seriatim* in a book, with remarks at the side accounting, as far as may be, for abnormalities of growth. A large collection of well-kept records of this kind would be of the highest value, not only from an anthropometric but from a sanitary point of view, using that term in its widest sense.

TABLE VIII.—Range in the HEIGHT of Males at each Age and in the several Classes.

(For further details see Tables VIII*a*, VIII*b*, VIII*c*, and VIII*d*.)

Age in Years	Total number of Observations.	Median Value					Range in Height at each Age: Between Upper and Lower Fourths					Range in Height at each Age: Between Upper and Lower Tenths				
		Classes				Average of all Classes	Classes				Average of all Classes	Classes				Average of all Classes
		1	2	3	4		1	2	3	4		1	2	3	4	
		inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches
8–	309	—	—	46·9	47·0	47·0	—	—	3·2	3·4	3·3	—	—	·1	6·1	6·1
9–	514	—	—	49·4	49·1	49·3	—	—	3·0	3·0	3·0	—	—	5·6	6·0	5·8
10–	1533	53·9	52·7	50·9	51·0	52·1	2·7	2·7	3·0	2·9	2·8	5·2	5·3	5·8	6·0	5·6
11–	1766	55·2	53·8	52·3	52·7	53·5	3·1	3·2	3·2	3·1	3·2	6·4	6·3	5·9	5·8	6·1
12–	1980	57·1	55·3	53·6	53·5	54·9	3·4	3·7	3·2	3·7	3·5	6·4	6·6	6·3	7·0	6·6
13–	2743	59·0	57·5	55·3	56·7	57·1	3·8	3·7	2·9	2·7	3·3	7·4	7·2	6·1	5·3	6·5
14–	3419	61·2	59·5	—	59·3	60·0	4·5	4·5	—	3·4	4·1	8·6	8·5	—	6·6	7·9
15–	3497	63·7	62·2	61·9	61·3	62·3	4·5	4·6	2·5	4·0	3·9	8·5	8·6	5·1	7·4	7·4
16–	2780	66·4	65·0	63·6	63·0	64·5	3·7	4·4	2·5	3·7	3·6	7·3	8·5	4·7	7·2	6·9
17–	2745	67·9	66·8	65·8	64·7	66·3	3·5	4·0	2·5	3·2	3·3	6·6	7·1	5·1	6·2	6·3
18–	2305	68·3	67·4	66·4	65·4	66·9	3·4	4·2	3·3	2·9	3·5	6·6	7·1	6·4	5·8	6·5
19–	1434	68·6	67·4	66·5	66·1	67·2	3·3	2·9	3·3	3·1	3·2	6·6	5·7	6·5	5·8	6·2
20–	880	69·1	67·8	67·0	66·5	67·6	3·4	3·5	3·1	2·8	3·2	6·7	6·4	6·5	5·5	6·3
21–	757	68·9	66·9	67·0	66·5	67·3	3·4	3·6	3·3	2·8	3·3	6·3	6·1	6·0	5·7	6·0
22–	516	69·0	67·7	67·2	66·5	67·6	3·2	2·9	3·4	3·3	3·2	6·5	5·7	6·3	6·4	6·2
23–	592	68·5	67·5	67·3	66·2	67·4	3·7	3·7	3·3	2·9	3·4	7·0	7·2	6·7	5·3	6·6
24–	517	68·8	67·2	67·0	66·4	67·4	2 8	3·2	3·1	3·3	3·1	5·2	6·9	6·5	6·0	6·2
25–	357	—	67·7	67·4	66·3	67·1	—	2·4	3·4	2·9	2·9	—	5·3	6·8	5·5	5·9
26–	315	—	68·0	67·3	66·4	67·2	—	3·0	3·6	2·2	2·9	—	5·2	7·1	5·2	5·8
27–	255	(69·4)	68·6	67·6	66·8	67·7	(3·1)	3·8	3·2	2·3	3·1	(6·0)	6·8	6·5	4·7	6·0
28–	300	—	68·1	67·4	66·6	67·4	—	3·6	3·2	3·0	3·3	—	6·1	6·5	4·7	5·8
29–	242	—	68·2	67·4	66·9	67·5	—	3·6	2·8	3·1	3·2	—	6·2	5·6	6·6	6·1
30–	1010	(69·7)	67·9	67·5	66·7	67·4	(3·1)	3·2	3·4	3·1	3·2	(5·8)	5·2	6·2	5·7	5·7
35–	824	—	68·0	67·6	67·0	67·5	—	2·7	3·4	2·8	3·0	—	5·5	6·5	5·8	5·9
40–	658	(69·0)	68·2	67·5	66·8	67·5	(3·2)	3·3	3·5	3·0	3·3	(6·8)	7·0	6·6	6·0	6·5
45–	441	—	68·1	67·5	66·3	67·3	—	2·7	3·6	3·4	3·2	—	5·2	6·7	6·2	6·0
50–	185	—	—	68·2	66·5	67·4	—	—	4·0	3·7	2·6	—	—	7·7	8·0	5·2

NOTE.—The ages under Class I., to which the entries within brackets ( ) apply, were grouped differently to those in the other classes (*see* Table VIII*a*). It has therefore been necessary to exclude those entries from the 'Average of all Classes.'

TABLE VIII*a*.—Range in the HEIGHT of Males at each Age.

CLASS I.—Professional (Upper and Upper Middle Classes).

Age in years	Number of Observations	Median	Average	Difference	Upper Quartile	Lower Quartile	Range between upper and lower fourths	Upper Decile	Lower Decile	Range between upper and lower tenths	Maximum — between	Minimum — between	Difference between maximum and minimum
		inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches
10–	101	53·9	53·7	+·2	55·1	52·4	2·7	56·3	51·1	5·2	57–58	48–49	9·0
11–	242	55·2	55·2	—	56·8	53·7	3·1	58·3	51·9	6·4	67–68	48–49	19·0
12–	490	57·1	57·3	−·2	59·0	55·6	3·4	60·6	54·2	6·4	70–71	48–49	22·0
13–	869	59·0	59·1	−·1	60·9	57·1	3·8	62·8	55·4	7·4	71–72	49–50	22·0
14–	966	61·2	61·3	−·1	63·5	59·0	4·5	65·8	57·2	8·6	72–73	50–51	22·0
15–	974	63·7	63·6	+·1	65·9	61·4	4·5	67·8	59·3	8·5	75–76	49–50	26·0
16–	1102	66·4	66·2	+·2	68·2	64·5	3·7	69·8	62·5	7·3	74–75	53–54	21·0
17–	1852	67·9	67·8	+·1	69·6	66·1	3·5	71·1	64·5	6·6	76–77	56–57	20·0
18–	1724	68·3	68·3	—	70·0	66·6	3·4	71·4	64·8	6·6	77–78	59–60	18·0
19–	951	68·6	68·6	—	70·2	66·9	3·3	71·9	65·3	6·6	77–78	60–61	17·0
20–	461	69·1	69·1	—	70·8	67·4	3·4	72·4	65·7	6·7	76–77	58–59	19·0
21–	364	68·9	68·7	+·2	70·6	67·2	3·4	72·2	65·9	6·3	76–77	62–63	15·0
22–	227	69·0	68·9	+·1	70·6	67·4	3·2	72·1	65·6	6·5	76–77	62–63	14·0
23–	114	68·5	68·6	−·1	70·4	66·7	3·7	72·2	65·2	7·0	75–76	62–63	13·0
24–	57	68·8	68·8	—	70·3	67·5	2·8	71·4	66·2	5·2	73–74	64–65	9·0
25–	107	69·4	69·1	+·3	70·7	67·6	3·1	72·1	66·1	6·0	74–75	61–62	13·0
30–	52	69·7	69·6	+·1	71·2	68·1	3·1	72·4	66·6	5·8	75–76	63–64	12·0
40–50	46	69·0	69·4	−·4	70·6	67·4	3·2	72·6	65·8	6·8	77–78	64–65	13·0

TABLE VIII*b*.—Range in the HEIGHT of Males at each Age.

CLASS II.—Commercial (Lower Middle Classes), Clerks, Shopkeepers, Shopmen, &c.

Age in years	Number of Observations	Median	Average	Difference	Upper Quartile	Lower Quartile	Range between upper and lower fourths	Upper Decile	Lower Decile	Range between upper and lower tenths	Maximum — between	Minimum — between	Difference between maximum and minimum
		inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches
10–	313	52·7	53·0	–·3	54·4	51·7	2·7	55·9	50·6	5·3	58–59	47–48	11·0
11–	687	53·8	53·8	—	55·3	52·1	3·2	56·9	50·6	6·3	60–61	47–48	13·0
12–	902	55·3	55·3	—	57·1	53·4	3·7	58·6	52·0	6·6	64–65	47–48	17·0
13–	857	57·5	57·4	+·1	59·4	55·7	3·7	61·3	54·1	7·2	67–68	49–50	18·0
14–	800	59·5	59·5	—	61·6	57·1	4·5	63·7	55·2	8·5	70–71	49–50	21·0
15–	544	62·2	62·2	—	64·5	59·9	4·6	66·5	57·9	8·6	71–72	53–54	18·0
16–	110	65·0	64·6	+·4	67·0	62·6	4·4	68·3	59·8	8·5	71–72	54–55	17·0
17–	107	66·8	66·6	+·2	68·6	64·6	4·0	70·1	63·0	7·1	72–73	58–59	14·0
18–	62	67·4	67·4	—	69·6	65·4	4·2	70·9	63·8	7·1	73–74	62–63	11·0
19–	63	67·4	67·6	–·2	68·9	67·0	2·9	70·6	64·9	5·7	72–73	63–64	9·0
20–	61	67·8	67·6	+·2	69·3	65·8	3·5	70·5	64·1	6·4	72–73	63–64	9·0
21–	51	66·9	66·8	+·1	68·4	64·8	3·6	69·8	63·7	6·1	72–73	62–63	10·0
22–	53	67·7	67·8	–·1	69·2	66·3	2·9	70·9	65·2	5·7	73–74	63–64	10·0
23–	59	67·5	67·4	+·1	69·3	65·6	3·7	71·0	63·8	7·2	72–73	61–62	11·0
24–	62	67·2	67·1	+·1	68·8	65·6	3·2	70·4	63·5	6·9	71–72	61–62	10·0
25–	47	67·7	67·9	–·2	69·0	66·6	2·4	70·9	65·6	5·3	73–74	64–65	9·0
26–	47	68·0	68·1	–·1	69·6	66·6	3·0	70·7	65·5	5·2	73–74	64–65	9·0
27–	27	68·6	68·1	+·5	70·1	66·3	3·8	71·3	64·5	6·8	72–73	63–64	9·0
28–	33	68·1	67·7	+·4	69·3	65·7	3·6	70·4	64·3	6·1	72–73	62–63	10·0
29–	26	68·2	68·0	+·2	69·8	66·2	3·6	71·0	64·8	6·2	72–73	63–64	9·0
30–	85	67·9	67·7	+·2	69·3	66·1	3·2	70·4	65·2	5·2	72–73	63–64	9·0
35–	82	68·0	68·1	–·1	69·3	66·6	2·7	70·9	65·4	5·5	74–75	62–63	12·0
40–	43	68·2	68·2	—	69·7	66·4	3·3	71·8	64·8	7·0	75–76	63–64	12·0
45–	36	68·4	68·0	+·4	69·5	66·8	2·7	70·7	65·5	5·2	71–72	60–61	11·0
50–	16	—	—	—	—	—	—	—	—	—	—	—	—

TABLE VIIIc.—Range in the HEIGHT of Males at each Age.

CLASS III.—Agricultural Labourers, Gardeners, Miners, Sailors, Fishermen, &c.

Age in years	Number of Observations	Median	Average	Difference	Upper Quartile	Lower Quartile	Range between upper and lower fourths	Upper Decile	Lower Decile	Range between upper and lower tenths	Maximum — between	Minimum — between	Difference between maximum and minimum
		inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches
8–	133	46·9	47·0	−·1	48·5	45·3	3·2	49·9	43·8	6·1	54–55	40–41	14·0
9–	156	49·4	49·1	+·3	51·0	48·0	3·0	52·2	46·6	5·6	55–56	42–43	13·0
10–	783	50·9	50 9	—	52·4	49·4	3·0	53·8	48·0	5·8	58–59	44–45	14·0
11–	597	52·3	52·3	—	53·9	50·7	3·2	55·3	49·4	5·9	58–59	46–47	12·0
12–	395	53·6	53·7	−·1	55·3	52·1	3·2	56·9	50·6	6·3	60–61	45–46	15·0
13–	403	55·3	55·3	—	56·7	53·8	2·9	58·4	52·3	6·1	62–63	48–49	14·0
14–	9	—	—	—	—	—	—	—	—	—	—	—	—
15–	515	61·9	61·8	+·1	63·1	60·6	2·5	64·4	59·3	5·1	70–71	55–56	15·0
16–	177	63·6	63·6	—	64·8	62·3	2·5	66·0	61·3	4·7	71–72	59–60	12·0
17–	75	65·8	65·9	−·1	67·1	64·6	2·5	68·4	63·3	5·1	71–72	61–62	10·0
18–	148	66·4	66·5	−·1	68·2	64·9	3·3	69·6	63·2	6·4	73–74	62–63	11·0
19–	143	66·5	66·9	−·4	68·4	65·1	3·3	70·3	63·8	6·5	74–75	62–63	12·0
20–	183	67·0	66·9	+·1	68·5	65·4	3·1	70·1	63·6	6·5	74–75	58–59	16·0
21–	177	67·0	67·2	−·2	68·8	65·5	3·3	70·3	64·3	6·0	72–73	60–61	12·0
22–	127	67·2	67·3	−·1	69·0	65·6	3·4	70·5	64·2	6·3	73–74	62–63	11·0
23–	274	67·3	67·4	−·1	68·9	65·6	3·3	70·8	64·1	6·7	76–77	59–60	17·0
24–	258	67·0	67·1	−·1	68·5	65·4	3·1	70·3	63·8	6·5	74–75	61–62	13·0
25–	218	67·4	67·5	−·1	69·2	65·8	3·4	71·0	64·2	6·8	74–75	60–61	14·0
26–	194	67·3	67·4	−·1	69·2	65·6	3·6	71·3	64·2	7·1	74–75	57–58	17·0
27–	162	67·6	67·8	−·2	69·4	66·2	3·2	71·2	64·7	6·5	74–75	58–59	16·0
28–	208	67·4	67·3	+·1	68·9	65·7	3·2	70·4	63·9	6·5	75–76	59–60	16·0
29–	163	67·4	67·5	−·1	68·9	66·1	2·8	70·4	64·8	5·6	74–75	62–63	12·0
30–	745	67·5	67·6	−·1	69·3	65·9	3·4	70·7	64·5	6·2	75–76	60–61	15·0
35–	631	67·6	67·6	—	69·3	65·9	3·4	70·9	64·4	6·5	76–77	59–60	17·0
40–	551	67·5	67·7	−·2	69·4	65·9	3·5	71·0	64·4	6·6	76–77	59–60	17·0
45–	392	67·5	67·5	—	69·3	65·7	3·6	70·7	64·0	6·7	77–78	59–60	18·0
50–	147	68·2	68·1	+·1	70·1	66·1	4·0	71·8	64·1	7·7	74–75	60–61	14·0
60–	34	67·6	67·9	−·3	69·5	66·1	3·4	72·2	64·2	8·0	73–74	62–63	11·0

TABLE VIII*d*.—Range in the HEIGHT of Males at each Age.

CLASS IV.—Artisans, Workers in Wood, Metals, Stone, Engravers, Printers, &c.

Age in years	Number of Observations	Median	Average	Difference	Upper Quartile	Lower Quartile	Range between upper and lower fourths	Upper Decile	Lower Decile	Range between upper and lower tenths	Maximum — between	Minimum — between	Difference between maximum and minimum
		inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches	inches
4–	21	38·8	38·5	+ ·3	39·6	37·3	2·3	40·1	36·2	3·9	40–41	35–36	5·0
5–	37	40·1	40·1	—	41·2	39·0	2·2	42·4	38·0	4·4	43–44	35–36	8·0
6–	40	42·9	43·3	– ·4	44·6	41·7	2·9	46·5	40·7	5·8	48–49	39–40	9·0
7–	53	45·9	45·7	+ ·2	47·0	44·4	2·6	48·2	42·9	5·3	50–51	41–42	9·0
8–	176	47·0	47·1	– ·1	48·8	45·4	3·4	50·1	44·0	6·1	51–52	41–42	10·0
9–	358	49·1	48·9	+ ·2	50·6	47·6	3·0	52·1	46·1	6·0	56–57	42–43	14·0
10–	336	51·0	50·7	+ ·3	52·4	49·5	2·9	53·8	47·8	6·0	58–59	42–43	16·0
11–	240	52·7	52·7	—	54·2	51·1	3·1	55·5	49·7	5·8	60–61	47–48	13·0
12–	193	53·5	53·7	– ·2	55·6	51·9	3·7	57·6	50·6	7·0	60–61	43–44	17·0
13–	614	56·7	56·8	– ·1	58·1	55·4	2·7	59·7	54·4	5·3	64–65	49–50	15·0
14–	1653	59·3	59·6	– ·3	61·2	57·8	3·4	63·2	56·6	6·6	71–72	50–51	21·0
15–	1464	61·3	61·4	– ·1	63·3	59·3	4·0	65·2	57·8	7·4	73–74	51–52	22·0
16–	1391	63·0	62·8	+ ·2	64·7	61·0	3·7	66·3	59·1	7·2	71–72	52–53	19·0
17–	711	64·7	64·7	—	66·3	63·1	3·2	67·9	61·7	6·2	73–74	56–57	17·0
18–	371	65·4	65·6	– ·2	67·0	64·1	2·9	68·8	63·0	5·8	71–72	55–56	16·0
19–	277	66·1	66·2	– ·1	67·7	64·6	3·1	69·2	63·4	5·8	72–73	58–59	14·0
20–	175	66·5	66·5	—	67·8	65·0	2·8	69·3	63·8	5·5	73–74	62–63	11·0
21–	165	66·5	66·8	– ·3	68·1	65·3	2·8	69·8	64·1	5·7	74–75	61–62	13·0
22–	109	66·5	66·6	– ·1	68·2	64·9	3·3	70·0	63·6	6·4	72–73	61–62	11·0
23–	145	66·2	66·4	– ·2	67·8	64·9	2·9	69·2	63·9	5·3	71–72	62–63	9·0
24–	140	66·4	66·5	– ·1	68·2	64·9	3·3	69·7	63·7	6·0	72–73	61–62	11·0
25–	92	66·3	66·5	– ·2	67·9	65·0	2·9	69·4	63·9	5·5	71–72	61–62	10·0
26–	74	66·4	66·4	—	67·4	65·2	2·2	69·0	63·8	5·2	72–73	60–61	12·0
27–	66	66·8	66·7	+ ·1	67·9	65·6	2·3	69·0	64·3	4·7	70–71	60–61	10·0
28–	59	66·6	66·7	– ·1	67·9	64·9	3·0	69·0	64·3	4·7	73–74	62–63	11·0
29–	53	66·9	66·8	+ ·1	68·4	65·3	3·1	70·2	63·6	6·6	73–74	60–61	13·0
30–	180	66·7	66·7	—	68·2	65·1	3·1	69·4	63·7	5·7	73–74	60–61	13·0
35–	111	67·0	67·1	– ·1	68·5	65·7	2·8	70·2	64·4	5·8	72–73	61–62	11·0
40–	64	66·8	66·7	+ ·1	68·2	65·2	3·0	69·8	63·8	6·0	72–73	60–61	12·0
45–	16	66·3	66·9	– ·6	68·5	65·1	3·4	70·5	64·3	6·2	73–74	63–64	10·0
50–	22	66·5	66·5	—	68·5	64·8	3·7	70·2	62·2	8·0	73–74	60–61	13·0

TABLE IX.—Range in the WEIGHT of Males at each Age and in the several Classes.

(For further details see Tables IX*a*., IX*b*., IX*c*., and IX*d*.)

Age in Years	Total number of Observations	Median Value					Range in Weight at each Age									
							Between Upper and Lower Fourths					Between Upper and Lower Tenths				
		Classes				Average of all Classes	Classes				Average of all Classes	Classes				Average of all Classes
		1	2	3	4		1	2	3	4		1	2	3	4	
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
10–	303	74·2	64·4	—	—	69·3	11·7	11·5	—	—	11·6	29·6	20·3	—	—	25·0
11–	578	77·6	67·4	—	—	72·5	11·5	11·4	—	—	11·5	22·6	21·6	—	—	22·1
12–	779	84·7	73·6	—	—	79·2	13·8	12 2	—	—	13·0	26·3	22·8	—	—	24·6
13–	1614	90·7	78·0	—	83·7	84·1	16·9	14·5	—	11·8	14·4	30·8	27·4	—	23·2	27·1
14–	2448	100·0	85·5	—	90·7	92·1	20·8	24·1	—	15·3	20·1	40·1	33·5	—	30·2	34·6
15–	3018	113·8	97·1	99·7	100·3	102·7	25·3	22·7	22·8	21·9	23·2	45·7	42·9	34·0	36·0	39·7
16–	2235	129·9	122·0	122·6	111·8	121·6	25·3	29·0	16·2	19·7	22·6	43·1	51·1	29·3	37·3	40·2
17–	2496	141·2	128·0	132·3	121·5	130·8	21·0	19·1	22·6	19·8	20·6	39·3	41·5	38·0	35·7	38·6
18–	2150	145·8	136·6	138·8	129·2	137·6	20·4	19·4	24·3	19·4	20·9	39·6	35·6	47·6	37·0	40·0
19–	1438	147·2	139·2	138·9	130·8	139·0	19·3	18·6	18·9	21·3	19·5	38·1	34·9	38·8	40·0	38·0
20–	851	151·7	141·8	144·0	136·4	143·5	18·6	25·9	21·3	17·6	20·9	37·2	38·1	37·6	38·1	37·8
21–	737	152·4	140·6	147·9	134·8	143·9	20·4	14·7	18·0	17·5	17·7	38·5	29·4	37·5	37·2	35·7
22–	542	153·5	142·2	149·7	137·3	145·7	19·9	20·8	24·4	21·2	21·6	37·5	44·3	41·7	38·2	40·4
23–	551	150·7	145·0	151·0	140·1	146·7	20·8	15·3	22·7	18·4	19·3	43·8	31·9	53·4	34·1	40·8
24–	483	149·7	147·8	151·3	142·5	147·8	18·9	21·1	19·8	23·0	20·7	34·9	41·3	40·1	44·1	40·1
25–	330	—	146·7	153·4	141·7	147·3	—	23·3	23·3	22·9	23·2	—	39·3	45·2	42·5	42·3
26–	296	—	149·2	151·7	138·3	146·4	—	19·0	25·0	20·5	21·5	—	42 2	48·0	35·6	41·9
27–	253	(155·9)	150·5	155·3	145·4	150·4	(23·3)	25·1	20·7	20·6	22·1	(40·1)	41·6	43·9	41·3	42·3
28–	296	—	151·9	154·4	146·7	151·0	—	24·1	23·3	18·1	21·8	—	64·7	46·5	40·6	50·6
29–	233	—	152·5	157·3	146·0	151·9	—	21·1	20·0	13·4	18·2	—	46·3	41·2	41·9	43·1
30–	940	(170·0)	158·2	157·4	146·6	154·1	(32·0)	26·0	23·6	29·2	26·3	(59·7)	47·0	51·6	59·0	52·5
35–	816	—	161·5	158·4	154·8	158·2	—	32·7	24·4	23·1	26·7	—	60·9	55·1	51·8	55·9
40–	646	(174·0)	165·5	160·4	147·8	157·9	(44·9)	33·8	27·1	25·7	28·9	(74·5)	67·5	55·7	56·9	60·0
45–	451	—	171·3	159·7	146·5	159·2	—	40·0	27·9	28·2	32·0	—	71·5	55·8	67·8	65·0
50–60	166	—	172·5	166·9	148·8	162·7	—	41·0	37·3	34·2	37·5	—	65·9	69·4	68·9	68·1

NOTE.—The ages under Class I., to which the entries within brackets ( ) apply, were grouped differently to those in the other classes (*see* Table IX*a*.) It has therefore been necessary to exclude those entries from the 'Average of all Classes.'

TABLE IXa.—Range in the WEIGHT of Males at each Age.

CLASS I.—Professional (Upper and Upper Middle Classes).

Age in years	Number of Observa-tions	Median	Average	Difference	Upper Quartile	Lower Quartile	Range between upper and lower fourths	Upper Decile	Lower Decile	Range between upper and lower tenths	Maximum — between	Minimum — between	Difference between maximum and minimum
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.
10–	92	74·2	74·0	+ ·2	78·9	67·2	11·7	82·9	63·3	29·6	90– 95	55– 60	35·0
11–	185	77·6	78·7	−1·1	84·3	72·8	11·5	90·7	68·1	22·6	100–105	55– 60	45·0
12–	369	84·7	84·9	− ·2	91·7	77·9	13·8	98·8	72·5	26·3	115–120	55– 60	60·0
13–	621	90·7	91·6	− ·9	99·6	82·7	16·9	107·3	76·5	30·8	140–145	55– 60	85·0
14–	748	100·0	102·2	−2·2	112·1	91·3	20·8	124·0	83·9	40·1	160–165	60– 65	100·0
15–	652	113·8	114·3	− ·5	126·8	101·5	25·3	137·3	91·6	45·7	175–189	70– 75	109·5
16–	834	129·9	129·5	+ ·4	141·1	118·8	25·3	150·1	107·0	43·1	175–189	75– 80	109·5
17–	1705	141·2	141·7	− ·5	151·8	130·8	21·0	161·7	122·4	39·3	189–203	90– 95	103·5
18–	1638	145·8	146·4	− ·6	156·2	135·8	20·4	166·0	126·4	39·6	203–217	100–105	107·5
19–	940	147·2	148·5	−1·3	157·4	138·1	19·3	168·5	130·4	38·1	203–217	105–110	102·5
20–	451	151·7	152·4	− ·7	161·4	142·8	18·6	171·3	134·1	37·2	189–203	90– 95	103·5
21–	365	152·4	152·7	− ·3	162·1	141·7	20·4	171·5	133·0	38·5	203–217	115–120	92·5
22–	215	153·5	152·8	+ ·7	162·2	142·3	19·9	171·6	134·1	37·5	189–203	115–120	78·5
23–	112	150·7	151·5	− ·8	161·9	141·1	20·8	172·5	128·7	43·8	175–189	115–120	64·5
24–	56	149·7	149·6	+ ·1	159·3	140·4	18·9	166·4	131·5	34·9	189–203	110–115	83·5
25–	115	155·9	156·3	− ·4	167·3	144·0	23·3	180·3	140·2	40·1	203–217	110–115	97·5
30–	48	170·0	172·5	−2·5	187·8	155·8	32·0	207·2	147·5	59·7	217–231	120–125	101·5
40–	44	174·0	174·6	− ·6	193·8	148·9	44·9	216·0	141·5	74·5	245–259	135–140	114·5
50–70	18	171·5	171·5	—	—	—	—	—	—	—	—	—	—

TABLE IX*b*.—Range in the WEIGHT of Males at each Age.

CLASS II.—Commercial (Lower Middle Classes): Clerks, Shopkeepers, Shopmen, &c.

Age in years	Number of Observations	Median	Average	Difference	Upper Quartile	Lower Quartile	Range between upper and lower fourths	Upper Decile	Lower Decile	Range between upper and lower tenths	Maximum — between	Minimum — between	Difference between maximum and minimum
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
10–	211	64·4	65·2	− ·8	70·4	58·9	11·5	75·5	55·2	20·3	80– 85	50– 55	30·0
11–	393	67·4	68·0	− ·6	73·5	62·1	11·4	79·5	57·9	21·6	95–100	45– 50	50·0
12–	410	73·6	73·2	+ ·4	77·9	65·7	12·2	83·9	61·1	22·8	90– 95	45– 50	45·0
13–	353	78·0	80·1	−2·1	85·7	71·2	14·5	93·5	66·1	27·4	120–125	55– 60	65·0
14–	304	85·5	89·5	−4·0	101·2	77·1	24·1	104·3	70·8	33·5	130–135	55– 60	75·0
15–	244	97·1	99·4	−2·3	110·9	88·2	22·7	121·4	78·5	42·9	145–150	65– 70	80·0
16–	55	122·0	122·2	− ·2	137·5	108·5	29·0	146·9	95·8	51·1	160–165	70– 75	90·0
17–	38	128·0	128·8	− ·8	138·3	119·2	19·1	150·0	108·5	41·5	160–165	95–100	65·0
18–	39	136·6	135·1	+1·5	145·2	125·8	19·4	151·9	116·3	35·6	160–165	100–105	60·0
19–	69	139·2	138·6	+ ·6	147·8	129·2	18·6	157·7	122·8	34·9	170–175	100–105	70·0
20–	52	141·8	143·1	−1·3	153·8	127·9	25·9	161·9	123·8	38·1	189–203	110–115	84·5
21–	51	140·6	140·9	− ·3	147·2	132·5	14·7	155·5	126·1	29·4	189–203	95–100	98·5
22–	51	142·2	145·5	−3·3	155·0	134·2	20·8	170·8	126·5	44·3	189–203	100–105	93·5
23–	57	145·0	146·8	−1·8	154·5	139·2	15·3	165·0	133·1	31·9	175–189	115–120	64·5
24–	57	147·8	147·1	+ ·7	156·8	135·7	21·1	168·8	127·5	41·3	175–189	110–115	69·5
25–	45	146·7	148·5	−1·8	160·8	137·5	23·3	168·9	129·6	39·3	175–189	115–120	64·5
26–	46	149·2	154·2	−5·0	161·5	142·5	19·0	177·2	135·0	42·2	217–231	120–125	101·5
27–	26	150·5	149·2	+1·3	160·5	135·4	25·1	170·8	129·2	41·6	175–189	110–115	69·5
28–	33	151·9	156·1	−4·2	165·8	141·7	24·1	196·0	131·3	64·7	203–217	125–130	82·5
29–	26	152·5	154·3	−1·8	165·0	143·9	21·1	178·8	132·5	46·3	189–203	105–110	88·5
30–	87	158·2	158·5	− ·3	169·3	143·3	26·0	183·3	136·5	47·0	217–231	105–110	116·5
35–	80	161·5	166·6	−5·1	180·5	147·8	32·7	201·3	140·4	60·9	245–259	125–130	125·0
40–	39	165·5	169·0	−3·5	183·4	149·6	33·8	208·0	140·5	67·5	245–259	120–125	129·5
45–	33	171·3	168·2	+3·1	185·8	145·8	40·0	205·3	133·8	71·5	217–231	120–125	101·5
50–	16	172·5	173·4	− ·9	191·3	150·3	41·0	210·0	144·1	65·9	217–231	130–135	91·5

TABLE IXc.—Range in the WEIGHT of Males at each Age.

CLASS III.—Agricultural Labourers, Gardeners, Miners, Sailors, Fishermen, &c.

Age in years	Number of Observations	Median	Average	Difference	Upper Quartile	Lower Quartile	Range between upper and lower fourths	Upper Decile	Lower Decile	Range between upper and lower Tenths	Maximum — between	Minimum — between	Difference between maximum and minimum
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
15–	676	99·7	100·6	– ·9	111·8	89·0	22·8	117·8	83·8	34·0	140–145	60– 65	80·0
16–	169	122·6	122·2	+ ·4	130·1	113·9	16·2	136·9	107·6	29·3	155–160	90– 95	65·0
17–	80	132·3	131·5	+ ·8	143·1	120·5	22·6	151·1	113·1	38·0	160–165	80– 85	80·0
18–	135	138·8	138·7	+ ·1	150·3	126·0	24·3	161·7	114·1	47·6	189–203	80– 85	113·5
19–	140	138·9	140·2	–1·3	149·0	130·1	18·9	161·3	122·5	38·8	189–203	95–100	98·5
20–	175	144·0	144·3	– ·3	154·7	133·4	21·3	163·2	125·6	37·6	175–189	110–115	69·5
21–	164	147·9	147·8	+ ·1	156·1	138·1	18·0	166·1	128·6	37·5	189–203	105–110	88·5
22–	167	149·7	150·6	– ·9	163·0	138·6	24·4	171·1	129·4	41·7	189–203	110–115	83·5
23–	279	151·0	152·8	– 1·8	163·2	140·5	22·7	184·4	131·0	53·4	217–231	105–110	116·5
24–	250	151·3	151·9	– ·6	161·2	141·4	19·8	171·3	131·2	40·1	189–203	115–120	78·5
25–	224	153·4	154·1	– ·7	164·9	141·6	23·3	178·2	133·0	45·2	203–217	110–115	97·5
26–	192	151·7	154·1	–2·4	165·5	140·5	25·0	180·7	132·7	48·0	203–217	115–120	92·5
27–	171	155·3	156·7	–1·4	165·3	144·6	20·7	181·1	137·2	43·9	203–217	115–120	92·5
28–	213	154·4	155·1	– ·7	165·9	142·6	23·3	179·4	132·9	46·5	203–217	110–115	97·5
29–	161	157·3	158·0	– ·7	167·2	147·2	20·0	179·8	138·6	41·2	189–203	125–130	68·5
30–	700	157·4	159·2	–1·8	169·3	145·7	23·6	188·5	136·9	51·6	259–273	110–115	153·5
35–	631	158·4	160·5	–2·1	170·6	146·2	24·4	191·7	136·6	55·1	259–273	110–115	153·5
40–	541	160·4	162·8	–2·4	174·6	147·5	27·1	192·8	137·1	55·7	259–273	105–110	158·5
45–	371	159·7	161·2	–1·5	174·1	146·2	27·9	191·0	135·2	55·8	245–259	110–115	139·5
50–	129	166·9	170·9	–4·0	188·3	151·0	37·3	208·8	139·4	69·4	259–273	115–120	148·5
60–	24	162·5	170·9	–8·4	183·4	152·5	30·9	229·4	132·5	96·9	231–245	120–125	115·5

TABLE IX*d*.—Range in the WEIGHT of Males at each Age.

Class IV.—Artisans, Workers in Wood, Metal, Stone, Engravers, Printers, &c.

Age in years	Number of Observations	Median	Average	Difference	Upper Quartile	Lower Quartile	Range between upper and lower fourths	Upper Decile	Lower Decile	Range between upper and lower tenths	Maximum — between	Minimum — between	Difference between maximum and minimum
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
13–	640	83·7	84·0	– ·3	90·0	78·2	11·8	96·2	73·0	23·2	110–115	55– 60	55·0
14–	1396	90·7	92·3	–1·6	99·2	83·9	15·3	108·9	78·7	30·2	135–140	55– 60	80·0
15–	1446	100·3	101·4	–1·1	113·0	91·1	21·9	119·9	83·9	36·0	150–155	60– 65	90·0
16–	1177	111·8	112·2	– ·4	122·1	102·4	19·7	131·0	93·7	37·3	160–165	70– 75	90·0
17–	673	121·5	121·5	—	130·1	110·3	19·8	139·3	103·6	35·7	165–168	75– 80	89·0
18–	338	129·2	129·3	– ·1	138·9	119·5	19·4	148·1	111·1	37·0	168–175	80– 85	89·0
19–	289	130·8	131·1	– ·3	140·9	119·6	21·3	151·5	111·5	40·0	189–203	90– 95	103·5
20–	173	136·4	136·4	—	144·8	127·2	17·6	155·4	117·3	38·1	175–189	100–105	79·5
21–	157	134·8	136·2	–1·4	144·2	126·7	17·5	155·7	118·5	37·2	175–189	105–110	74·5
22–	109	137·3	138·6	–1·3	148·3	127·1	21·2	158·5	120·3	38·2	189–203	105–110	88·5
23–	103	140·1	140·2	– ·1	148·9	130·5	18·4	156·9	122·8	34·1	175–189	110–115	69·5
24–	120	142·5	143·4	– ·9	153·2	130·2	23·0	165·4	121·3	44·1	203–217	105–110	102·5
25–	61	141·7	139·9	+1·8	151·4	128·5	22·9	160·0	117·5	42·5	168–175	105–110	64·0
26–	58	138·3	142·2	–3·9	152·5	132·0	20·5	162·5	126·9	35·6	168–175	110–115	59·0
27–	56	145·4	146·9	–1·5	157·0	136·4	20·6	164·8	123·5	41·3	217–231	105–110	116·5
28–	50	146·7	148·0	–1·3	155·0	136·9	18·1	169·0	128·4	40·6	203–217	115–120	92·5
29–	46	146·0	148·1	–2·1	154·0	140·6	13·4	166·9	125·0	41·9	189–203	110–115	83·5
30–	153	146·6	150·1	–3·5	162·7	133·5	29·2	181·5	122·5	59·0	231–245	110–115	97·5
35–	105	154·8	156·5	–1·7	166·1	143·0	23·1	183·8	132·0	51·8	217–231	115–120	106·5
40–	66	147·8	150·7	–2·9	161·4	135·7	25·7	183·2	126·3	56·9	189–203	110–115	83·5
45–	47	146·5	152·8	–6·3	164·5	136·3	28·2	192·0	124·2	67·8	217–231	110–115	111·5
50–	21	148·8	145·6	+3·2	160·0	125·8	34·2	176·8	107·9	68·9	203–217	105–110	102·5

TABLE X.—Range in the STRENGTH OF ARM of Males at each Age.

General Population.

Age in years	Number of Observations	Median	Average	Difference	Upper Quartile	Lower Quartile	Range between upper and lower fourths	Upper Decile	Lower Decile	Range between upper and lower tenths	Maximum — between	Minimum — between	Difference between maximum and minimum
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
11–	27	37·5	37·5	—	42·1	32·5	9·6	46·9	29·6	17·3	50– 55	25–30	25·0
12–	49	38·6	38·7	– ·1	44·1	33·1	11·0	53·8	34·9	18·9	50– 55	25–30	25·0
13–	119	42·9	44·2	–1·3	49·1	37·9	11·2	56·3	33·3	23·0	80– 85	25–30	55·0
14–	375	45·1	47·0	–1·9	52·5	38·1	14·4	67·3	33·4	33·9	105–110	20–25	85·0
15–	531	52·6	52·2	+ ·4	58·4	43·3	15·1	68·3	38·3	30·0	125–130	25–30	100·0
16–	438	56·6	58·2	–1·6	66·3	48·3	18·0	76·5	41·8	34·7	115–120	30–35	85·0
17–	388	64·4	67·8	–3·4	74·5	55·2	19·3	87·5	49·0	38·5	140–145	30–35	110·0
18–	415	73·9	74·2	– ·3	88·4	61·9	26·5	97·7	57·4	40·3	135–140	40–45	95·0
19–	382	73·0	76·4	–3 4	86·1	64·1	22·0	100·5	62·0	38·5	145–150	40–45	105·0
20–	259	76·1	77·9	–1·8	87·5	65·9	21·6	93·3	59·5	33·8	120–125	45–50	75·0
21–	213	78·9	80·2	–1·3	90·5	69·4	21·1	98·3	62·7	35·6	130–135	50–55	80·0
22–	202	79·6	81·7	–2·1	90·6	71·3	19·3	99·5	65·2	34·3	135–140	50–55	85·0
23–	192	79·4	80·9	–1·5	89·1	69·9	19·2	97·3	65·0	32·3	155–160	40–45	115·0
24–	159	78·3	79·7	–1·4	87·3	70·4	16·9	96·4	64·5	31·9	120–125	50–55	70·0
25–	578	81·9	83·5	–1·6	91·4	74·1	17·3	100·5	70·5	30·0	150–155	50–55	100·0
30–	534	75·3	77·5	–2·2	85·8	68·1	17·7	94·7	60·9	33·8	155–160	35–40	120·0
40–	144	76·3	76·5	– ·2	84·7	68·1	16·6	93·0	57·5	35·5	145–150	35–40	110·0
50–60	34	71·6	74·6	–7·0	80·8	64·3	16·5	97·5	58·1	39·4	110–115	50–55	60·0

Inspector-General LAWSON, *who has prepared the Tables XI. to XIV. on* EYESIGHT, *has contributed the following remarks upon them.*

The acuteness of vision has been tested by finding the distance at which the individual under trial could distinguish the dots on the cards issued by the Committee, so as to count them readily. These cards contain eighteen square dots of one-fifth of an inch wide placed irregularly in two groups, the distances from centre to centre of the contiguous dots varying from 2 diameters to 3·16; their intervals may accordingly be taken at one diameter less, or from 1 to 2·16. Of these intervals five are of 1 diameter, six of 1·24, two of 1·83, and three of 2·16, and, if the acuteness of vision were fairly tested, it must have been equal to separating the dots with the intervals of one diameter sufficiently, at the distance noted for each individual, to enable him to count them.

On approaching such a card, from a distance, the dots with the larger interspaces become distinct, while those with the smaller still seem continuous; but after a few trials many of those under test will become aware that the elongated-looking dots are made up of two, though they be too far off for the eye to separate them.

The individuals examined have been distributed in five classes according to the scheme detailed in Table III. of the Committee's Report for 1880; the details for each class are given in the Tables XI. to XIV.[1] On looking over these the fluctuations in the distance for consecutive years of age are far too great to admit of any satisfactory conclusions; to obviate this the ages have been grouped in five-yearly periods up to thirty, after which ten-yearly periods have been employed; these reduce the fluctuations materially and afford much more harmonious results, as will be seen in the following abstract.

Distance at which the test-dots were distinguished at different ages in each of the five classes, with a general mean for the II. III. IV. and V. Classes, and a separate one for the IV. and V. Classes.

Ages	Class I.		Class II.		Class III.		Class IV.		Class V.		General Mean of Classes II. to V.		Mean of Classes IV. and V.	
	Obs.	Distance in Feet	Obs.	Distance in Feet	Obs.	Distance in Feet	Obs.	Distance in Feet	Obs.	Distance in Feet	Obs.	Distance in Feet	Obs.	Distance in Feet
10–14	52	29·2	—	—	—	—	—	—	—	—	—	—	—	—
15–19	63	27·7	14	54·3	57	54·6	97	51·5	18	62·7	186	53·7	115	53·2
20–24	15	26·8	27	54·5	145	52·0	97	48·1	53	56·1	322	51·7	150	50·9
25–29	2	47·5	15	48·5	80	50·9	48	47·1	39	52·8	182	50·1	87	49·7
30–39	7	42·5	22	52·3	77	51·3	41	45·6	25	50·9	165	50·0	66	47·6
40–49	2	47·5	8	38·8	33	51·9	24	45·7	13	48·3	78	48·0	37	46·6
50–59	1	7·5	4	48·5	13	51·6	6	40·0	5	36·4	28	46·0	11	40·2
60 and upwds.	2	55·0	1	27·5	7	43·9	—	—	5	35·5	13	39·5	5	35·5
Total . .	144	—	91	—	412	—	313	—	158	—	974	—	471	—

[1] For the reasons stated below, it has not been considered necessary to give the Tables for Class I. in a separate form.

The details in this table show that the distance at which the dots could be counted by those under 25 years of age in Class I. was about half that found for each of the other four classes, while above 25 this difference was greatly reduced. This discrepancy has arisen from the persons in Class I. having been examined in a hall where the space was limited and the light not very good; but it is so great as to prevent the numbers for the first class being combined with those for the other four in a general mean; consequently the latter only, which are sufficiently regular among themselves to justify the proceeding, have been employed for this purpose, and the results are given in the 6th column of the table. From this it appears that, in a mixed town and country population of 974, those from 15 to 19 could distinguish the test-dots at a mean distance of 53·7 feet; this diminished through 51·7 feet between 20 and 24, to 50·0 feet from 30 to 39; a decrease of 2 feet in ten years went on from 40 to 59; and after 60 this was nearly doubled. There is here an approximate measure of the reduction of the range of vision with advancing age, which, taking the distance the dots were visible from 15 to 19 as the unit, may be represented for the subsequent ages as follow:—

Ages . .	15–	20–	25–	30–	40–	50–	60–
Range of vision	1	·96	·93	·93	·89	·86	·74

The influence of town or country occupations and surroundings may now be examined. Class III. may be taken to represent the latter, but it is advisable to combine Classes IV. and V., to increase the number as well as to embrace a greater variety of occupations, to illustrate the former. The results are given in the last column in the above table. Class II. includes persons in a different sphere of life from III., IV., and V., and their numbers are too few at present to afford a sufficient basis to work on; while Class I., as has been already mentioned, is not available. Taking the mean distance at which the dots were distinguished at 15 to 19 as the unit as above, the ranges at subsequent ages were as follow:—

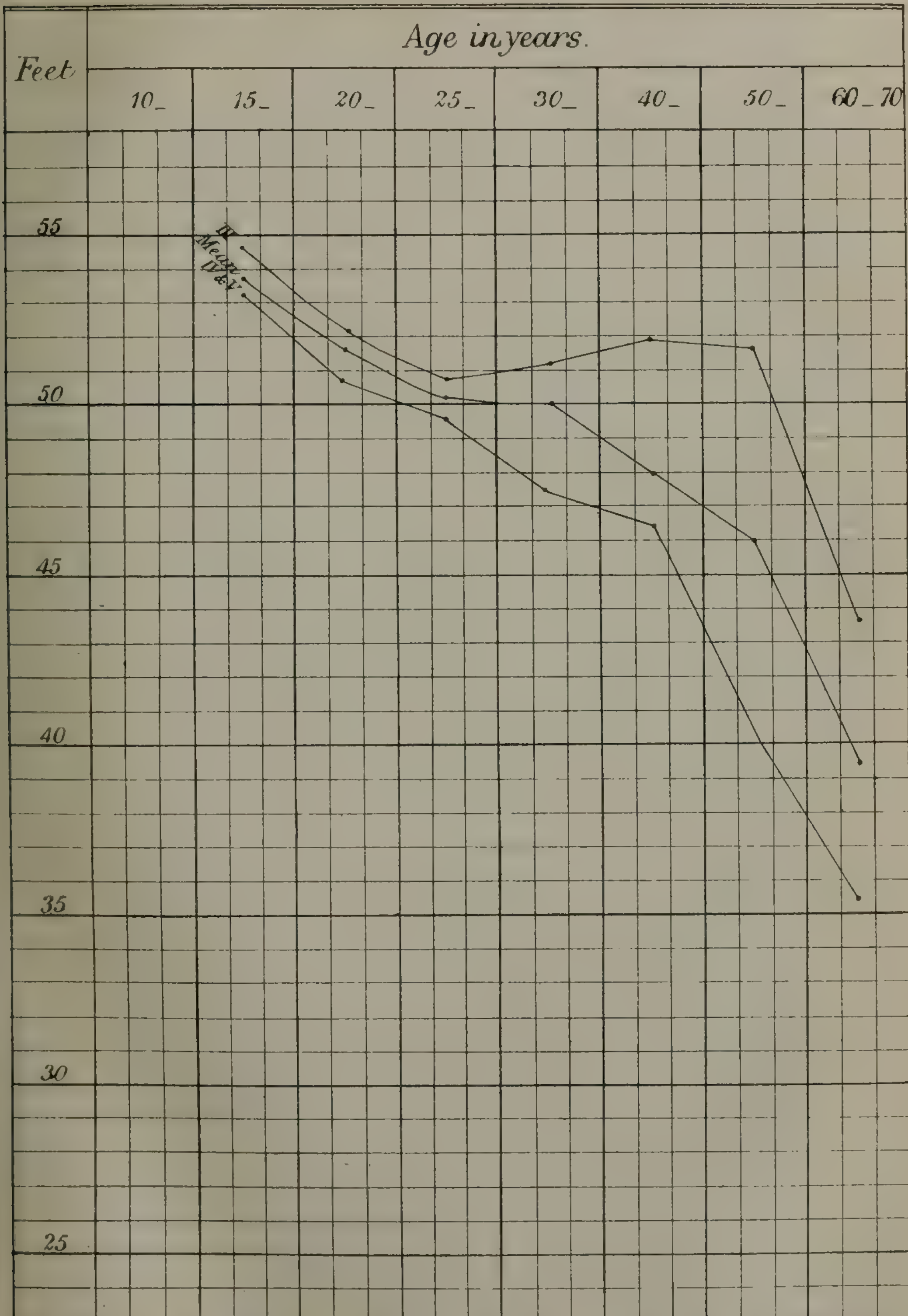
Ages	15–	20–	25–	30–	40–	50–	60–
Class III., country . .	1	·95	·93	·94	·95	·95	·80
Class IV. and V., town .	1	·96	·93	·89	·88	·76	·67

Though Class III. embraces 412 individuals, it is evident from the course of the ratios from the ages of 30 to 59 that they are not sufficiently numerous to neutralise irregular fluctuations; nevertheless, when compared with those for Classes IV. and V. in the next line, there can be no doubt that country life and occupations are far less injurious to vision as age advances than residence in towns with its concomitant circumstances. As the smaller distance at which the dots were distinguished by persons under 19 in the towns than in the country may be due in a great measure to the difference in the brightness of illumination in these positions, it is prudent to postpone the consideration of how far people at that age have their vision affected by town life until sufficient material be accumulated. These facts will be readily appreciated by examining the diagram on Plate IV.

These remarks will afford a fair idea of the scope of the present inquiry; but many more observations, especially at the higher ages, are required to place the results on a firmer basis. With a sufficient number of observations the influence of any single occupation, or of a series of

SIGHT

Diagram showing the average distance at which dots ⅕ inch square were distinguished by different classes at different ages.



III = Class III. Mean = Classes II to V. IV & V = Classes IV & V.

Illustrating the Report of the Anthropometric Committee.

Spottiswoode & Co. Lith. London.

occupations, involving the employment of the sight in a similar manner might be tested, and could afford materials for very important conclusions.

NOTE.—The conditions under which the acuteness of vision is tested have a marked influence on the results. The most favourable circumstances for bringing out the acuteness of vision in persons whose eyes are healthy, and their refracting power normal, are to view a dark body against a well-illuminated bright-coloured background some way behind it. For short distances the upright or wire of an iron fence; for greater distances a pole or flagstaff projected against the clear sky beyond, are suitable objects, from either of which the distance of the observer can be measured. The writer, for instance, though his vision is no longer so acute as formerly, can perceive distinctly at 200 yards' distance, in good daylight, the upright of an iron hurdle presenting a breadth of 0·36 inch from his point of observation, and projected against a newly gravelled walk; and, some years ago, he had frequent opportunities of observing a flagstaff, on a hill, the smallest part of which was not more than six inches in diameter, yet in favourable weather that was distinctly visible three miles off. The angle the object subtended at the eye in the former instance is $10''\cdot3$, and in the latter $6''\cdot7$, and in each case it was considerably within the extreme limit of vision. It will be observed, however, that though these objects were narrow, they were of considerable length, and this extension in a direction perpendicular to their smallest diameter enabled the eye to seize and retain the latter, while, had its length not exceeded its breadth there would have been far more difficulty in finding it in the first instance, and in keeping the eye fixed steadily on it afterwards. In practice objects which appear square or circular, as presented to the eye, cannot be distinguished under such small angles, and only become distinctly visible at distances proportionately much shorter. When they are dark, on a light ground in the same plane, the range of vision is reduced still more.

In arranging his test-types Snellen proceeded on the assumption that the normal eye could perceive an object subtending an angle of $1'$, and consequently he gave the lines forming his letters such a breadth that they should reach the eye under an angle of $1'$, when held at the distance indicated in the accompanying instructions; but to admit of the various parts of the letters being perceptible their height was fixed at $5'$, or five times the breadth of their limbs. These letters afford a very convenient practical test of the various alterations the sight may have undergone; but, as will appear immediately, owing to their forms and the small distance between their different parts, they are not adapted for determining quantitatively its greatest range under normal conditions. The test-dots which were introduced originally to ascertain the fitness of recruits for military service seem better suited for this purpose, though, as they were employed to ensure the minimum range of vision required for military service, which is far within that of the ordinary healthy eye, their capabilities were never fully considered or developed.

A single test-dot, say a square of $\frac{1}{5}$ of an inch of a side, will be visible as far as any combination of them in which the single dots are distinguishable; their arrangement in groups is merely to provide a check on the person under trial, by varying the number exposed and requiring him to count them; but when investigating the extreme limit of vision a difficulty arises here, which did not present itself when

Table XI. Class II.—Age and Strength of Sight (distance at which dots $\frac{1}{5}$-inch square have been distinguished).

Feet	15 yrs	16–	17–	18–	19–	20–	21–	22–	23–	24–	25–	30–	35–	40–	45–	50–	55–	60–	Total
0–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10–	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	2
15–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20–	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
25–	—	—	1	—	—	—	1	—	—	—	1	1	1	—	—	—	—	1	6
30–	—	—	1	—	—	—	—	1	1	2	3	3	—	—	1	—	—	—	12
35–	—	—	—	—	1	—	1	—	—	—	1	1	—	1	2	—	—	—	7
40–	—	—	—	—	—	—	2	—	—	—	3	2	—	1	—	—	1	—	9
45–	—	—	—	3	1	2	1	—	1	—	1	1	1	—	—	—	2	—	13
50–	—	—	—	—	1	—	—	—	—	1	—	2	2	1	—	—	—	—	7
55–	1	—	—	—	1	—	2	1	1	—	2	1	1	1	—	1	—	—	12
60–	—	—	1	1	—	1	—	—	—	—	3	—	—	—	—	—	—	—	6
65–	—	—	—	—	—	1	—	1	1	1	—	2	—	—	—	—	—	—	6
70–	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	2
75–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
80–	—	—	—	—	1	—	—	—	—	—	—	3	—	—	—	—	—	—	4
85–	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	2
90–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
95–	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
100 and upwards	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
	1	—	4	4	5	6	7	3	5	6	15	16	6	5	3	1	3	1	91
Average for each year	57·5	—	55·0	51·3	55·5	64·2	44·6	52·5	43·5	66·7	48·5	52·5	51·7	40·5	35·8	57·5	45·5	27·5	—
And for five and ten yearly periods	54·3					54·5					48·5	52·3		38·8		48·5		27·5	—

TABLE XII. CLASS III.—AGE and STRENGTH OF SIGHT (distance at which dots 1/5-inch square have been distinguished).

Feet	16 yrs.	17–	18–	19–	20–	21–	22–	23–	24–	25–	30–	35–	40–	45–	50–	55–	60	Total
0–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1
10–	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	2
15–	—	—	—	—	—	1	—	—	1	2	—	—	—	—	—	—	—	4
20–	—	1	—	—	—	1	2	1	—	1	—	1	1	—	—	1	—	9
25–	—	—	—	2	3	1	—	—	2	4	2	1	—	—	1	—	—	16
30–	—	—	1	4	1	2	3	4	2	5	1	4	2	—	—	1	—	30
35–	—	1	1	—	2	3	1	2	3	11	8	2	—	1	—	—	1	36
40–	—	1	2	1	2	3	3	1	2	3	4	3	2	—	1	1	5	34
45–	—	—	2	4	3	8	—	1	1	8	4	6	3	1	—	—	—	41
50–	—	1	5	2	6	11	4	4	3	8	5	1	5	1	—	—	—	56
55–	—	4	6	3	2	8	1	1	4	14	—	3	6	2	2	1	1	58
60–	—	—	1	4	3	4	1	3	1	10	6	5	2	1	3	—	—	44
65–	1	—	1	—	3	2	3	2	3	10	8	2	5	—	1	—	—	41
70–	1	—	—	—	1	2	2	1	2	3	3	5	—	—	—	—	—	20
75–	—	2	1	2	—	1	2	1	—	—	—	—	—	—	1	—	—	10
80–	—	—	—	1	—	1	—	—	—	1	—	—	—	—	—	—	—	3
85–	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	2
90–	—	—	—	2	—	1	1	1	—	—	—	—	—	—	—	—	—	5
95–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
100 and upwards	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Totals . . .	2	10	20	25	27	49	23	22	24	80	43	34	26–	7	9	4	7	412
Averages for each year	70·0	54·0	53·3	54·7	51·8	52·5	53·6	52·3	49·2	50·9	52·0	50·4	53·3	46·8	57·5	38·8	43·9	51·9
And for five and ten yearly periods	54·6				52·0					50·9	51·3		51·9		51·6		43·9	—

TABLE XIII. CLASS IV.—AGE and STRENGTH OF SIGHT (distance at which dots $\frac{1}{5}$-inch square have been distinguished).

Feet	15 yrs	16–	17–	18–	19–	20–	21–	22–	23–	24–	25–	30–	35–	40–	45–	50–	55–	60–	Total
0–	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
5–	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	2
10–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
15–	—	—	—	—	—	—	—	—	—	—	1	2	—	—	—	—	—	—	3
20–	—	—	—	2	—	1	2	2	—	2	3	2	2	3	2	—	1	—	22
25–	—	—	1	2	—	2	4	—	2	—	4	1	2	1	—	1	—	—	20
30–	—	—	2	5	2	3	3	2	2	3	6	5	—	3	—	—	—	—	36
35–	—	—	3	1	2	1	1	3	—	1	4	2	2	1	2	—	—	—	23
40–	1	—	2	3	6	—	3	2	1	3	2	2	1	2	1	—	—	—	29
45–	—	—	9	9	6	6	—	1	1	1	5	3	2	1	—	—	—	—	44
50–	—	1	3	4	—	3	2	1	1	1	7	3	—	1	1	—	1	—	29
55–	—	—	1	5	2	5	2	2	2	2	6	3	—	1	1	—	—	—	32
60–	—	—	2	4	2	3	2	2	2	2	7	3	1	1	—	2	—	—	33
65–	—	—	—	—	1	2	—	2	—	1	—	—	—	—	—	—	—	—	6
70–	—	—	1	4	1	2	1	—	—	—	1	—	—	1	—	—	—	—	11
75–	—	—	—	2	—	—	—	—	—	—	1	2	1	—	—	—	—	—	6
80–	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	2
85–	—	—	—	1	—	—	—	1	—	—	—	—	1	—	—	—	—	—	3
90–	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
95–	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	2
100–	—	—	—	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	3
105–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
110–	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
115–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
120–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
125–	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
130–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
135 and upwards	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	2
Totals . . .	1	1	25	46	24	29	22	18	12	16	48	28	13	17	7	3	3	—	313
Averages for each year	42·5	52·5	50·8	51·2	52·5	51·5	43·0	48·3	53·9	44·7	47·1	44·5	47·9	48·5	38·9	50·8	29·2	—	47·2
And for five and ten yearly periods	51·5					48·1					47·1	45·6		45·7		40·0		—	—

Table XIV. Class V.—Age and Strength of Sight (distance at which dots ⅕-inch square have been distinguished).

Feet	17 yrs	18–	19–	20–	21–	22–	23–	24–	25–	30–	35–	40–	45–	50–	55–	60–	Total
0–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10–	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	2
15–	—	—	—	—	—	—	—	—	1	—	1	—	—	1	—	—	3
20–	—	—	—	—	—	—	—	—	—	1	1	—	—	—	1	—	3
25–	—	—	—	—	—	—	1	—	—	—	—	—	3	—	—	2	6
30–	—	—	—	—	—	—	—	—	1	—	1	1	—	—	—	1	4
35–	—	—	—	—	—	—	1	1	1	—	1	—	—	—	1	—	5
40–	1	1	—	—	1	1	—	—	4	1	—	—	—	—	—	1	10
45–	2	—	—	1	—	1	1	—	3	1	—	1	—	1	—	1	12
50–	1	—	—	1	4	1	1	1	2	1	1	—	2	—	—	—	15
55–	—	1	1	6	4	11	3	3	13	2	3	1	2	1	—	—	51
60–	—	4	1	3	1	—	—	1	8	3	4	2	1	—	—	—	28
65–	—	—	2	1	—	—	—	1	4	2	—	—	—	—	—	—	10
70–	—	—	2	—	—	1	1	—	1	1	—	—	—	—	—	—	6
75–	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
80–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
85–	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
90–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
95–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
100 and upwards	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Totals	4	8	6	12	11	15	8	7	39	12	13	5	8	3	2	5	158
Averages for each year .	47·5	67·5	66·3	58·3	56·6	56·5	51·3	56·1	52·8	56·3	46·0	52·5	45·6	40·8	30·0	35·5	—
And for five and ten yearly periods	62·7			56·1					52·8	50·9		48·3		36·4		35·5	—

recruits only were concerned, viz., the distance at which dots of the same size appear separate to the eye, and can be counted, varies with the space between them. Four rows of dots of $\frac{1}{5}$-inch square were placed on a card; those of the first row were separated from each other by spaces of the same size left blank; in the second row each dot was separated from those in its vicinity by $\frac{2}{5}$ of an inch; in the third row the distance of each dot from any other was $\frac{3}{5}$ of an inch, and in the fourth row $\frac{4}{5}$ of an inch; and a single dot was placed on one side 1·5 inch from the nearest one in the rows. These were exposed in the open air, on a bright day, in a situation affording a clear range of about 90 feet; at that distance from the card the single dot was quite perceptible, and those in the first, second, and third rows had the appearance of continued lines. On approaching the card the dots in the fourth row could be counted at 82 feet, those in the third at 74, in the second at 58, and in the first only at 36 feet. The ordinary cards of dots, therefore, on which these are separated by spaces varying from one to a little over two diameters can only give a comparative test of the acuteness of vision among those examined, and not an absolute one such as a card with intervals of not less than five times the diameter of the dots between every two of them would afford. Dots so arranged could not be grouped readily, but they could be shown in varying numbers to the person under trial, and his replies would indicate whether he were able to distinguish them.

Mr. ROBERTS'S *Report on the Observations on Eyesight and Colour-blindness made at Marlborough College by the* REV. T. A. PRESTON.

The difficulty experienced by many observers of obtaining sufficient space and light for testing the eyesight by the test-dots (which are distinguishable to the normal eye in good daylight at a distance of 19 yards) has induced the Committee to use Snellen's test-types, No. 1 and No. 10, as more convenient and trustworthy. No. 1 is a small type visible to the normal eye at the ordinary reading distance of from 12 to 20 inches, and No. 10 is a large thick type $\frac{1}{5}$th of an inch square, distinguishable by the normal eye at a distance of 10 feet.

The Rev. T. A. Preston, one of the masters at Marlborough College, has examined the eyesight and colour-sense of the whole of the boys and some of the masters at present in the College, and the following is an analysis of his returns. The observations include the age, the colour of the iris, the eyesight as tested by No. 1 and No. 10, and the letters composed of horizontal and vertical lines for astigmatism; and the colour-sense as tested by the methods of Dr. Daae and Professor Holmgren (and in a few instances by the solar spectrum), according to the book of tests which I have prepared for the use of the Committee ('The Detection of Colour-blindness and Imperfect Eyesight': Bogue).

AGE.—The ages of the boys range from 11 to 19 years, and those of the masters from 20 to 50 years, five of the latter being over 40 years.

COLOUR OF EYES.—The following Table shows the colour of the eyes of the boys and masters under 40 years of age, divided into two groups—those who are under and those who are above the age of 15 years.

Colour of Eyes	Under 15			Over 15			Total		
	No.	Per cent.		No.	Per cent.		No.	Per cent.	
Dark blue . .	2	·9	65·2	7	1·9	64·5	9	1·5	64·7
Blue . . .	62	28·1		98	27·9		160	27·8	
Light blue . .	32	14·5		51	14·4		83	14·4	
Grey . . .	48	21·7		72	20·3		120	21·0	
Brown grey (green)	23	10·4	34·8	36	10·1	35·5	59	10·3	35·3
Light brown (hazel)	52	23·5		83	23·4		135	23·5	
Dark brown . .	2	·9		7	2·0		9	1·5	

From the similarity of the percentages of the two periods it would appear that little change takes place in the colour of the iris after the age of 15 years, as the dark eyes are barely one per cent. greater in the later than the earlier period. The proportion of fair to dark eyes is 64·7 to 35·3, or about two fair to one of dark complexion.

Colour-blindness.—Of the 600 boys and masters, 15, or 2·5 per cent. were found to be colour-blind, a proportion which has been found to exist elsewhere in the same class of boys, and about half that which exists in the uneducated classes. The following table shows the nature of the chromatic defect, and the condition of the eyesight and the colour of the hair and iris.

No.	Age	Colour of Hair	Colour of Eyes	Colour-blindness	Test-type No. 1	Test-type No. 10	Astigmatism.
					in.	ft.	
1	12–8	Golden (fair red) .	Dark grey .	Red-blind .	16	11	Horizontal
2	12–4	Dark brown .	Light blue .	Red-blind .	13	7	Vertical
3	14–1	Dark brown .	Blue . .	Red-blind .	18	4	
4	15–4	Red . .	Grey . .	Red-blind .	18	8	Horizontal
5	16	Black . .	Dark brown .	Red-blind .	16	3½	Horizontal
6	17	Dark golden (red) .	Dark blue .	Red-blind .	17	10	Horizontal
7	17–3	Dark brown .	Blue . .	Red-blind .	21	13	Vertical
8	14–2	Dark brown .	Light brown.	Green-blind	15	7	Horizontal
9	14–3	Red . .	Blue . .	Green-blind	29	15	
10	14–11	Red . .	Grey . .	Green-blind	20	9	Vertical
11	16–2	Dark brown .	Light blue .	Green-blind	19	12	
12	17–0	Black . .	Light brown .	Violet-blind	22	12	
13	13	Light brown.	Blue . .	Imperfect .	16	6	
14	17–4	Brown . .	Grey . .	Imperfect .	18	7	
15	28	Dark brown .	Light brown .	Imperfect .	28	13	Horizontal

Having observed in my private examinations that colour-blindness was very frequent in persons with red hair, Mr. Preston has furnished me with the colour of the hair in his cases. The Table of the relative prevalence of different coloured hair published in the Anthropometric Committee's Report for 1880 shows that red hair prevails in the professional classes (in which are included the Marlborough boys) to the extent of 9·06 per cent., while in conjunction with complete colour-blindness in the above Table it exists to the extent of 41·7 per cent. Light-coloured eyes are slightly in excess, and imperfect eyesight is more prevalent among the colour-blind, but the number of observations are too few to form any safe conclusion on these heads.

EYESIGHT.—The following Tables show the quality of the eyesight as tested by Snellen's test-types.

NEAR VISION.—The Distance at which Test-type No. 1 can be read.[1]

Distance in inches	Marlborough Boys — Age last Birthday									Masters — Age		Total	Per cent.	
	11	12	13	14	15	16	17	18	19	20–40	40–50			
0	—	—	—	—	—	—	—	—	—	—	1	1	·2	
4	—	—	—	—	1	1	—	—	—	—	—	2	·3	
6	—	—	—	1	1	2	—	1	1	—	1	7	1·1	8·9
8	—	—	—	1	1	2	2	—	—	—	—	6	1·0	
10	—	2	1	4	2	1	3	—	—	—	—	13	2·2	
12	1	1	3	4	5	6	2	—	—	2	1	25	4·1	
14	1	6	5	6	9	5	1	1	—	—	—	34	5·7	
16	3	4	13	14	17	11	6	2	—	1	—	71	11·8	51·7
18	2	4	14	17	24	12	7	1	—	3	—	84	14·0	
20	2	6	15	27	30	21	14	2	1	2	1	-121-	20·2	
22	1	2	12	19	21	16	9	4	2	—	1	87	14·5	
24	1	—	3	13	14	22	11	5	—	1	—	70	11·7	
26	—	—	1	6	11	8	3	4	1	4	—	38	6·3	
28	—	—	2	3	3	8	4	1	—	3	—	24	4·0	39·4
30	—	—	—	1	2	4	1	2	—	2	—	12	2·0	
32	—	—	—	—	1	2	—	—	—	—	—	3	·5	
34	—	—	—	1	—	—	—	—	—	—	—	1	·2	
36	—	—	—	—	—	—	1	—	—	—	—	1	·2	
Total	11	25	69	117	142	121	64	23	5	18	5	600	100·	
Average	18·4	16·4	18·3	19·0	19·1	20·1	20·0	21·8	19·0	—	—	—	—	
	17·7			19·4			20·2			22·1	11·4	—	—	

[1] Specimen of Test-type No. 1.—(12 inches.)

437, 35, 66, 680, 956, 8634, 473, 533, 3536, 4303. During the minority of Queen Mary, the Palace of Holyrood was burnt, as well as the city, by the English forces under the Earl of Hertford; soon after, it was repaired and enlarged beyond its present size. At that time it is said to have consisted of no fewer than five courts, the most westerly of which was the largest. Great part of the Palace of Holyrood House was burnt by the soldiers of Cromwell; but, at the Restoration, it was

Distant Vision.—The Distance at which Test-type No. 10 can be read.[1]

Distance in feet	Marlborough Boys									Masters		Total	Per cent.	
	Age last Birthday									Age				
	11	12	13	14	15	16	17	18	19	20–40	40–50			
½	—	—	—	—	—	2	—	1	1	—	1	5	·8	
1	—	—	—	4	6	6	5	—	—	2	—	23	3·8	
2	—	—	2	3	5	8	1	2	—	1	—	22	3·7	
3	—	—	—	—	2	5	3	—	1	1	1	13	2·0	
4	—	—	—	1	3	4	1	—	—	—	—	9	1·5	30·5
5	—	—	2	4	4	2	3	2	—	—	—	17	3·0	
6	1	1	3	4	3	2	—	—	—	1	—	15	2·5	
7	1	5	6	5	5	6	3	—	—	—	1	32	5·2	
8	—	3	9	9	10	10	3	3	—	—	—	47	8·0	
9	2	4	9	15	17	8	5	—	—	1	1	62	10·3	
10	2	2	14	17	28	16	14	2	—	—	—	95	15·8	39·4
11	2	7	10	17	17	12	9	4	—	2	—	80	13·3	
12	3	3	6	15	16	13	3	1	3	4	1	68	11·3	
13	—	—	5	8	14	9	4	2	—	2	—	44	7·3	
14	—	—	2	10	4	8	4	—	—	—	—	28	4·7	
15	—	—	1	2	4	6	4	4	—	—	—	21	3·5	
16	—	—	—	1	3	2	1	1	—	1	—	9	1·5	30·1
17	—	—	—	1	—	1	1	—	—	1	—	4	·7	
18	—	—	—	—	1	1	—	1	—	1	—	4	·7	
20	—	—	—	—	—	—	—	—	—	1	—	1	·2	
22	—	—	—	1	—	—	—	—	—	—	—	1	·2	
Total	11	25	69	117	142	121	64	23	5	18	5	600	100·	
Average	10·0	9·4	9·5	10·0	9·6	9·1	9·4	10·2	8·0	—	—	—	—	
	9·6			9·6			9·2			10·5	6·5	—	—	

[1] Specimen of Test-type No. 10.—(10 feet.)

V Z B D F H K

Judging by the averages it would seem that the near sight (as tested by No. 1) improves from year to year up to 40, but this apparent improvement is probably due to the greater ease with which the type is read by the elder pupils and masters. From the great distances at which the No. 1 type has been read, it is probable that considerable efforts have been made to distinguish it at the greatest possible distance rather than at the distance at which it could be read with ease and fluency. The curve formed by the whole number of observations at all ages is remarkably uniform, the 'mean' being at 20 inches, and the corresponding groups above and below the mean being nearly identical in value. Normal near vision exists in 51·7 per cent., while 39·4 are above, and 8·9 per cent. below the average.

The averages do not show any change in the distant vision (as tested by No. 10) up to the age of 40 years, a result which contrasts favourably with similar observations made in German schools and universities, where short-sight has been found to increase rapidly with the extended period of education. The curve formed by the total number of observations is, however, irregular, and consists of two curves having a chief mean at

10–11 feet, and a minor one at 2–3 feet. This latter curve is due to the accession after the age of 13 years of an abnormal amount of imperfect eyesight (short-sight and over-sight) which is too slight relatively to the total number of observations to influence the averages. 39·4 per cent. possess normal distant vision, while 30·1 per cent. are above, and 30·5 per cent. below the average.

Astigmatism.—Tested by means of the letters composed of horizontal and vertical lines, 68·2 per cent. of the Marlborough boys and masters are returned as more or less astigmatic, or in the proportion of nearly two to one; the ratio of the horizontal to the vertical defect being 1 to 1·2. Mr. Preston is not quite satisfied with the result of his observations on this subject, as he had no means of checking the statements of the boys.

Ignorance of the Names of Colours.—In a recent report on the examination of 27,927 school-children for colour-blindness by Dr. Joy Jeffries, in America, the following remark on this subject occurs: 'Experience has abundantly shown me that but very few *boys* of the grammar or higher schools are familiar with colour-names of even the primary colours, and that still less can they correctly apply those names they do remember when shown coloured objects. Although prepared for this ignorance on the part of the boys to a certain extent, I confess I was astonished to find it so frequent and great. It seems almost impossible that a bright boy of fourteen, not colour-blind, should not know the word *green* or be able to apply it. Yet this does not give an extreme idea of the truth in reference to the ignorance of colour-names and their application among school-boys.' Being desirous to know if our English public school-boys are as ignorant of colour-names and their application as the boys of the same class in America, I submitted the above sentence to Mr. Preston, and the following is his reply: 'I cannot agree with Dr. Jeffries as to ignorance of colour-names. By this I mean reds, greens, &c. Of course *mauve*, *magenta*, &c., and what are called drapers' colours are not often known, but I have certainly had no difficulty in getting the names of the common colours. In fact it was quite the exception to meet with a boy who could not tell the names fairly well. The whole of the boys who proved to be colour-blind, except one, knew of their defect, and another boy was under the impression that he was colour-blind, but turned out on examination not to be so.'

Report of the Committee, consisting of Professor Leone Levi, Mr. Stephen Bourne, Mr. Brittain, Dr. Hancock, Professor Jevons, *and* Mr. F. P. Fellows, *appointed for the purpose of inquiring into and reporting on the present Appropriation of Wages, and other sources of income, and considering how far it is consonant with the economic progress of the people of the United Kingdom. Drawn up by* Professor Leone Levi.

If it were possible to ascertain, with any approach to accuracy, the present appropriation of wages and other sources of income of the people of the United Kingdom, it would certainly be of the greatest utility, as it would afford a valuable aid in the consideration of some of those great problems which meet us on every side in our social economy. There are, in truth, no means for ascertaining either the absolute income or the true expenditure of the entire population, and any calculation of the same must, more or less, partake of the nature of an estimate. But even an estimate may be helpful, if founded on proper bases. Given certain data with respect to a limited number of cases, it is quite possible, by legitimate induction, to arrive at great results as applied to the whole population. Only let the data which form the bases of the calculation be certain and well established, and the result must be a close approximate to the real truth. What are all calculations regarding the expectation of life, but generalisations from certain given facts? The Northampton Table, upon which so many millions have been insured, was constructed by Dr. Price on the account kept at Northampton during the years 1735–1780, of the ages at death of only 4,689 persons who were buried in the parish of All Saints. It is not only, however, in matters of life and death that we observe a wonderful uniformity, certainty, and constancy. We find the Law of Nature operating alike on all men, influencing their moral and intellectual qualities, regulating their will, and controlling their habits and manners. And it is the beauty and glory of the statistical method, that it enables us to calculate the seemingly incalculable. With this instrument at hand, and with a good grip of the teaching of common experience, that which appears but a dream or a guess to the uninitiated, becomes to the mathematician and statistician a simple, natural, and reliable result.

Apart, however, from the difficulties attending any general inquiry of this nature, there are special obstacles to the ascertainment of the appropriation of wages and other income, in that there is a want of agreement in the scientific meaning of the word income,—in that it is not easy to distinguish the gross from the net income, and the income of the nation collectively from the income of the individuals composing it. Many attempts have been made to estimate the total income of the nation of late years. Mr. Gladstone, in one of his addresses, estimated it at 1,000,000,000*l.* The late Mr. Dudley Baxter, in his work on National Income, gave it at 813,000,000*l.* The writer made an estimate of the wages and earnings of the working classes in money or its equivalent, and found them to amount to 418,000,000*l.*, and Mr. Giffen, in a paper read before the Statistical Society, estimated the recent accumulations of capital in the United Kingdom at the rate of 240,000,000*l.* per annum. More might have been expected from the labours of the International Statistical Congress in this direction. That Congress, at its session at the Hague in 1869, expressed a wish that the delegates of different countries, and especially the heads of their statistical offices, should communicate to the future Congress the elements which the statistics of their countries supply for arriving at a statistical account, as complete as possible, of the income of the nation, whether according to the individual method, which implies a valuation of the individual income of the people, or according to the real method, that is, by a valuation of the different branches of production. But this desideratum has not yet been supplied.

Personal and National Income.

The ascertained or ascertainable income in the United Kingdom is that assessed to income tax on the declaration of the tax-payers, or upon other incontestable evidence. The unascertained and unascertainable is the amount of income not charged with that tax, which includes all incomes under 150*l.* a year, and probably many incomes up to, and exceeding that amount, though not sufficiently regular or certain, or centred in the head of the family, so as to come within the range of the income-tax.

The annual values of property and profits assessed and charged to income tax in the year ended April 5, 1880, were as follows :—

	Assessed £	Charged £
Schedule A. Lands, messuages, &c.	185,377,770	170,187,031
„ B. Occupation of lands	69,383,066	34,465,770
„ C. Funded debt, Foreign and Colonial funds	39,860,483	39,860,483
„ D. Trades and professions	249,489,398 [1]	215,577,122
„ E. Public offices	32,786,184	25,986,622
	576,896,901	486,077,028
Income of non-income-tax payers: lower, middle, and working classes	*500,000,000*	*500,000,000*
	1,076,896,901	*986,077,028*

But these different branches of income are not all derived from independent sources of production, or from the production, in each case, of new utilities. The income from interest in the British funds, represents a simple transfer from the nation to the fundholder within the same. The same remark applies to the income assessed for salaries for public officers under Schedule E. And Schedule D likewise comprises a large portion of professional incomes, which really constitute the expenditure of other classes. The difference between the amount assessed and the amount charged to income-tax arises mainly from the abatements made of 120*l.* on small incomes and allowances for life assurance. It is the amount assessed, therefore, that represents this portion of the income of the nation, which in the method suggested will stand as follows :—

	Income £
Schedule A	185,000,000
„ B	69,000,000
„ C	19,000,000
„ D	222,000,000
	495,000,000

In like manner, the income of non-income-tax payers is subject to the same distinction. The wages of soldiers and seamen, and of labourers in the Royal Dockyards, the wages of domestic servants and gardeners, the salaries of a large proportion of teachers, and of clergymen, amounting in all to upwards of 80,000,000*l.*, cannot be considered as independent incomes. Adding these sums, the results are as follows :—

	Total Income £
Income-tax paying	495,000,000
Non-income-tax paying	420,000,000
	915,000,000

[1] The remaining 27,000,000*l.* represents professional incomes.

What is Productive and what Unproductive Expenditure.

What is done with such annual income? How much of it is productively and how much unproductively expended? And what amount is set aside as capital for reproduction? Is, in short, the method of its appropriation consonant with the economic progress of the people of the United Kingdom? It is not an easy matter to say what amount of national income is productively expended. Productive consumption, said Mr. John Stuart Mill, is what is consumed by productive labourers, including the labour of direction as well as of execution, in keeping up or improving their health, strength, and capacity for work. Unproductive consumption is what is expended on pleasure or luxuries, whether by the idle or the industrious. That alone, according to Mr. Mill, is productive consumption which goes to maintain and increase the productive power of the community. But there is labour the end of which is not production but enjoyment, and yet the expenditure for which, within certain limits, may be perfectly consistent with the greatest efficiency of labour. Not all luxuries, not all enjoyments, are waste in a true economic sense. The human forces, unlike the physical, need rest and renovation, and whatever is expended for the purpose of giving it a fresh impetus for labour, may well be held to be productive expenditure. Any attempt, moreover, to determine whether the expenditure is productive or unproductive, by the character of the article for which the expenditure is incurred, as by its chemical composition, or nutritive value, would lead us to problems which lie beyond the province of the economist or statistician. The consumption of the people is greatly regulated by climate and temperature, by the constitution and habits of the people, and by the nature of their occupation. It is experience, not theory, that must guide us in the determination of the possibilities or impossibilities of certain economies.

Distribution of Expenditure.

The principal items of expenditure of a personal character are food and drink, house rent, furniture, fire and light, clothing, tobacco, education, literature, science and art, church and charity, servants, horses and carriages, and amusements. In calculating the expenditure for articles of food and drink and for clothing, a distinction must be made between the gross expenditure, which includes the expense of distribution and taxation, and the net expenditure, which represents the simple cost of the articles, whether imported or produced at home. Twenty per cent. has been added for the cost of distribution to represent retail prices, that rate not being too high remembering that between the importers and consumers there are always two and often three profits. The Co-operative Companies have in some cases led to the economy of one at least of these profits, but their dealings are not of sufficient magnitude to affect materially the calculation for the expenditure of the whole nation.

Population.

The population of the United Kingdom has been ascertained by the census of 1881 to be 35,246,562, of which we may estimate 17,000,000 males and 18,000,000 females, and as it affects some of our future calculations, it is well to remember that the urban population may be taken at 20,000,000 and the rural at 15,000,000. The details as to ages are not yet known, but in a general manner 55 per cent. are adults and 45 per cent. persons under age.

Articles of Food.

Bread.

In the expenditure for food, bread holds the first place, on account of its being shared in by the largest number of people, though in amount it stands second to meat. Mr. Caird, in his valuable work on the landed interest, calculated the quantity and value of wheat of home and foreign growth consumed annually in the United Kingdom as follows:—

	Quantity Cwts.	Value £
Home Growth . . .	55,000,000 . .	32,187,500
Foreign " . . .	55,000,000 . .	32,187,500
	Cwts. 110,000,000 . .	£64,375,000

Messrs. Lawes and Gilbert, in a paper read before the Statistical Society on the 11th May, 1880, gave the consumption of wheat for the average of three years, from 1876 to 1878, as follows:—

	Quantities available for consumption Qrs.	Value £
Home , . . .	10,198,253 . . .	24,670,579
Foreign	13,700,386 . . .	33,356,761
Total	23,898,639 . . .	£58,027,340

Take 60,000,000*l.* as the average of the two authorities, and add 25 per cent. for manufacture of bread and distribution, and the cost appears to be about 75,000,000*l.* In another form, take 110,000,000 cwt. as the consumption, or 12,320,000,000 lbs.; at 80 lbs. flour per cwt. wheat, they will give 9,856,000,000 lbs. flour. Assume that 280 lbs. flour will give 316,610,000 quartern loaves, at 6*d.* the quartern loaf the gross expenditure would be 77,500,000*l.*, whilst the net expenditure would be 60,000,000*l.*; the gross expenditure being at the rate of 1·41*d.*, and the net at the rate of 1·12*d.* per day for each individual in the kingdom.

Potatoes.

Next to bread, the potato is most largely used as farinaceous food, especially in Ireland. The home growth of potatoes was estimated by Mr. Caird at 111,000,000 cwts. According to the agricultural statistics for 1880, the number of acres under cultivation in the United Kingdom was 1,380,578 acres. Estimating the produce at 3 tons per acre, the total produce would be 82,835,000 cwts., and, at 6*s.* per cwt., the cost would be 24,850,000*l.* Add 9,750,000 cwts. imported, at an average price of 5·84*s.* per cwt., value 2,847,000*l.*, we have a total of 27,697,000*l.*, and, with 20 per cent. for distribution, 33,238,000*l.*, or in the proportion of 0·64*d.* as the gross, and 0·51*d.* as the net expenditure per day for each individual.

Vegetables.

Of the quantity of vegetable and fruit home-produce consumed there is no account, but the amount may be safely taken at half the value of potatoes, or 14,000,000*l.*, and, with 20 per cent. for distribution, 17,000,000*l.*, or in the proportion of 0·32*d.* as the gross, and 0·25*d.* as the net expenditure per day per person.

Meat.

The amount expended in meat is very large. Mr. Caird calculated the value of meat produced at home, in butcher's meat, bacon, ham, pork, &c., at 24,500,000 cwts., valued at 87,000,000*l.* And he added 6,300,000 cwts. of foreign growth, valued at 22,050,000*l.*, making in all 109,050,000*l.* We may test the consumption of meat by another process. We are indebted to the kindness of Mr. N. Stephen, the Clerk and Superintendent of the London Central Meat Market, for the quantity of meat there sold, which, in 1880, was 221,448 tons.[1] Add for meat slaughtered by butchers 20,200 tons, and we have a total of 241,674 tons, or 541,349,760 lbs., as representing approximately the quantity of meat consumed in the Metropolis. Take the population of what is called Greater London, which the Central Market supplies, at 4,760,000, and the consumption per head is 0·31 lbs. per day. The average wholesale price may be taken at $6\frac{1}{4}$*d.* per lb., and the average retail price at $7\frac{1}{2}$*d.* per lb. At the latter price, the amount spent in London alone, on meat, is 16,900,000*l.* Extend the calculation to the whole country at $\frac{1}{4}$-lb. per head, and at the same prices of $6\frac{1}{4}$*d.* and $7\frac{1}{2}$*d.* per lb. respectively the result is a total consumption of 3,193,750,000 lbs., at a cost of 83,000,000*l.* wholesale price, and 99,800,000*l.* retail, which give an average expenditure of 1·87*d.* as a gross, and 1·55*d.* as a net expenditure per day for each individual.

Fish.

The consumption of fish is considerable. Mr. Spencer Walpole, the Inspector of Fisheries, in a report to the Secretary of State, stated that in 1879, 135,000 tons of fish were brought, for consumption, into London; and that, upon a population of 3,500,000, it gave an average of 90 lbs. per head. Fish is largely consumed by the labouring classes; but London is exceptionally well supplied with fish, and for the whole population it is not safe to take more than 20 lbs. per head per annum. The price of fish varies considerably with the description and season of the year; salmon, soles, and turbot selling at considerably higher prices than herrings, mackerel, cod, and other kinds. Taking the total quantity consumed at 700,000,000 lbs.,[2] and the average price at 4*d.* per lb.

[1] The proportions were as follows:—

	Tons
Country killed	107,326
Town killed	80,905
General foreign (meat and produce)	7,381
American killed (fresh meat)	25,836
	221,248

[2] The quantity of fish conveyed by railway from each of the principal fishing ports, in the year 1878, was as follows:—

	Tons
England	176,652
Scotland	32,292
Ireland	6,894
	216,338

equal to 484,597,120 lbs. Allowing one-third more for fish consumed direct from the boats, the consumption would be 646,000,000 lbs.

wholesale and 5*d*. per lb. retail, the total value would be 11,700,000*l*. wholesale and 14,500,000*l*. retail, or in the proportion of 0·26*d*. as a gross, and 0·23*d*. as a net expenditure per day per person.

Butter and Cheese.

Butter and cheese are important articles of food. Mr. Caird estimated the home produce of these at 3,000,000 cwts., valued at 13,500,000*l*., and at a similar quantity and amount the butter and cheese imported. In 1880, however, the imports were 2,326,000 cwts. butter, and 1,775,000 cwts. cheese, of the collective value of 17,232,000*l*., making, with the home produce, a total of about 30,000,000*l*., and, with 20 per cent. for distribution, a total of 36,000,000*l*., or in the proportion of 0·67*d*. as a gross, and 0·56*d*. as a net expenditure per day per person.

Milk and Eggs.

The value of home-grown milk is estimated at 26,000,000*l*., and the value of eggs imported in 1880 at 2,300,000*l*., representing, probably, one-fourth of the total consumption, or 9,000,000*l*., giving an aggregate in milk and eggs of 35,000,000*l*., which, with 20 per cent. for distribution, amounts to 42,000,000*l*., or equal to 0·78*d*. as a gross, and 0·66*d*. as a net expenditure per day per person.

Fruit and other Articles of Import.

To these we must add the following articles of import, at their declared value, viz.: Fruit, raw and dry, 6,507,000*l*.; rice, 1,697,000*l*.; spices, 506,000*l*.; and confectionery, 568,000*l*. Total, 9,278,000*l*.; and, with 20 per cent. for distribution, 11,133,000*l*., equal to 0·19*d*. as a gross, and 0·17*d*. as a net expenditure per day per person.

Sugar.

Sugar is partly used as food, and partly as drink. According to the report of the Commissioners of Customs, the value of sugar retained for consumption, in 1880, was 22,770,000*l*. Deducting the quantity used in brewing, 1,136,000 cwts., value 1,200,000*l*., and adding the cost of refining upon at least the half of the raw sugar consumed, 9,000,000*l*., the entire cost may be taken at 24,700,000*l*., and, with 10 per cent. for profit and distribution, 27,000,000*l*., or 0·50*d*. as a gross, and 0·46*d*. as a net expenditure per day per person.

Tea and Coffee.

The value of tea retained for consumption, in 1880, was 8,809,000*l*. Add the duty, 3,964,000*l*., we have a total of 12,773,000*l*., and, with 20 per cent. for distribution, the total cost to consumers would be 15,327,000*l*., or 0·60*d*. as a gross, and 0·16*d*. as a net expenditure per day.

Of coffee and cocoa, the quantity retained for consumption was valued at 2,196,000*l*. Add duty, 330,000*l*., and 20 per cent. for profit and distribution, and we have a total of about 3,000,000*l*., or in the proportion of 0·05*d*. as a gross, and 0·04*d*. as a net expenditure per day per person.

Beer.

Of alcoholic drinks, the consumption is large. In the year ended 30th September, 1880, the quantity of malt brewed in the United Kingdom was 55,850,790 bushels. At 2 bushels to the barrel it would give 27,925,395 average barrels, or 1,005,314,220 average gallons of beer. Deducting the exports, 18,000,000 average gallons, the home consumption would be 987,000,000 gallons. One thousand million gallons is a safe number to take. The actual cost of beer is probably 7*d.* per gallon; and at that rate the cost is 29,000,000*l.*; but, at the selling price of 1*s.* 6*d.*, which includes duty (6,732,000*l.*) and profits of distribution, the consumers pay 75,000,000*l.*, or in the proportion of 1·40*d.*, the net cost being only 0·54*d.* per day per head.

Spirits.

The total consumption of British and foreign spirits in 1880 was 40,000,000 gallons. Taking the cost at 4*s.* per gallon and the sale price at 20*s.*, the entire cost would be 8,000,000*l.*, and the amount paid by consumers, including duty, 10*s.* per gallon, and profit of distribution, 40,000,000*l.*, or at the rate of 0·75*d.* as a gross, the net cost amounting only to 0·14*d.* per head per day.

Wine.

Of wine the value of the quantity retained for consumption was valued at 5,800,000*l.* Add duty 1,407,000*l.* and 25 per cent. for distribution, the total amount is 9,000,000*l.*, or in the proportion of 0·16*d.* as a gross expenditure, the net being 0·10*d.* per day per head.

Total Food and Drink.

Collectively the amount expended in articles of food and drink is as follows:—

	Total expenditure £	Original cost of home produce and imports £
Bread	77,500,000	60,000,000
Potatoes	33,200,000	27,700,000
Vegetables	17,000,000	14,000,000
Meat	99,800,000	83,000,000
Fish	14,500,000	11,700,000
Butter and cheese	36,000,000	30,000,000
Milk and eggs	42,000,000	35,000,000
Fruit, &c	11,100,000	9,300,000
Sugar	27,000,000	24,700,000
Tea	15,300,000	8,800,000
Coffee, &c.	3,000,000	2,200,000
Beer	75,000,000	29,000,000
Spirits	40,000,000	8,000,000
Wines	9,000,000	5,800,000
	£500,400,000	£349,200,000

Divided per head the different branches of expenditure for food and drink were as follows:—

	Gross, per day *d.*	Net, per day *d.*
Bread	1·41	1·12
Potatoes	·64	·51
Vegetables	·32	·25
Meat	1·87	1·55
Fish	·26	·23
Butter and cheese	·67	·56
Milk and eggs	·78	·66
Fruit, &c.	·19	·17

	Gross, per day	Net, per day
	d.	*d.*
Sugar	·50	·46
Tea	·60	·16
Coffee and Cocoa	·05	·04
Beer	1·40	·54
Spirits	·75	·14
Wine	·16	·10
	9·60*d.*	6·49*d.*

The consumption of imported articles of food and drink has largely increased of late years, as will be seen from the following comparison of the quantity retained for home consumption per head of the total population of the United Kingdom in 1840, 1860, and 1880, as given in the statistical abstract:—

		1840	1860	1880
Corn	lbs.	42·47	118·86	210·42
Potatoes	,,	0·01	2·18	31·63
Bacon and Hams	,,	0·01	1·27	15·96
Butter	,,	1·05	3·26	7·42
Cheese	,,	0·92	2·24	5·56
Eggs	No.	3·63	5·83	21·68
Sugar	lbs.	15·20	33·11	63·68
Tea	,,	1·22	2·67	4·59
Wine	gallons	0·25	0·23	0·46
Malt	British	1·59	1·45	1·60
Spirits	,,	0·83	0·74	0·84
,,	Foreign.	0·14	0·19	0·25

A large consumption of articles of food in great part imported is a sign of general prosperity, and is conducive to greater effectiveness of labour. There is no reason to suppose that home production has diminished of late years, except indeed as the consequence of deficient harvests on special years. The increasing imports therefore denote so much additional food consumed by the people. Mr. Stephen Bourne, in his interesting paper 'On our increasing dependence upon foreign supplies of food,' said, 'To be thus dependent upon extraneous sources for so large a portion of the national food may probably, to some minds, be the occasion of much anxiety, as rendering our very existence precarious, and as being derogatory to our national pride; but provided our circumstances be such as to preclude it resulting in financial embarrassment we shall find it to be in every respect advantageous, or at least to have so many benefits connected with it as to far outweigh any consideration of an opposite character.'

Articles of Dress.

Let us now pass to the amount expended in articles of dress.

Cotton.

According to Messrs. Ellison's Cotton Circular the home consumption of cotton was, in 1880, 184,373,000 lbs., which at the average price of 2·94*d.* per lb. would cost 2,250,000*l.* Taking 4½ yards for every pound of cotton, the number of yards produced would be 829,678,000. The average price of piece goods, white, printed, &c. exported in 1880 was 3·16*d.* per yard. Assuming 5*d.* per yard for the cotton goods consumed at home, their cost would be 17,280,000*l.* To this there must be added 1,500,000*l.* the value of lace, and 4,000,000*l.* of hosiery, besides 3,100,000*l.*, the value of cotton manufacture imported, making in all

25,800,000*l.*, and, with 20 per cent. for distribution, 31,000,000*l.*, or in the proportion of 0·58*d.* as a gross, and 0·48*d.* as a net expenditure per day per head.

Wool.

The quantity of wool left for home consumption in 1880, according to Messrs. Helmuth Schwartze & Co.'s circular, including domestic clip[1] and total imports of wool, alpaca, and mohair, was 370,000,000 lbs., besides 92,000,000 lbs. woollen rags, torn up or not, used as wool. Deducting the exports of woollen manufacture, which represent 90,000,000 lbs., the remainder, 280,000,000 lbs., may be taken as the quantity consumed at home; and at two yards to the pound and 2*s.* per yard, the cost would be 56,000,000*l.*, besides 7,650,000*l.* of woollen goods imported, making in all 63,650,000*l.*. But considerable quantities of wool are used in flannel, blankets, rugs, carpet, and articles for the household, not articles of dress. According to information kindly supplied by Messrs. John Scott & Co. the approximate consumption of wool and woollen goods may be calculated as follows:—For men's cloth the consumption is about 50 per cent. at 3*s.* per yard, 35 per cent. at 8*s.* 6*d.*, and 15 per cent. at 11*s.* per yard. For women's dress 50 per cent. at 6½*d.* per yard, 35 per cent. at 11*d.*, and 15 per cent. at 2*s.* 3*d.* per yard. And for women's mantle, jacket, and Ulster cloths 50 per cent. at 2*s.* 6*d.*, 35 per cent. at 6*s.*, and 15 per cent. at 10*s.* per yard. And at these calculations if only one dress per annum were used the cost would be 35,000,000*l.* It is safe, however, to assume a consumption of half as much for dress, making a total of 52,600,000*l.*, which, with 20 per cent. for distribution, amounts to 63,000,000*l.*, or in the proportion of 1·18*d.* as a gross, and 0·98*d.* as a net expenditure per head per day.

Linen.

There is a total want of detail regarding the consumption of linen, but it may be estimated at one-fourth of the consumption of cotton goods, viz., 6,400,000*l.*, and with 20 per cent. for distribution, 7,700,000*l.*, or in the proportion of 0·14*d.* as a gross, and 0·11*d.* as a net expenditure per person per day.

Silk.

In 1880 there were imported into the United Kingdom, of raw and thrown silk, 3,877,000 lbs., of which, however, there were exported 955,000 lbs., leaving for home consumption 2,922,000 lbs., say 3,000,000 lbs., which, at 5 yards to the pound, would give 15,000,000 yards. Deduct from this 6,200,000 yards exported, there remained for home consumption 8,800,000 yards. At 4*s.* per yard these would give a cost of about 1,700,000*l.* Add the import of silk manufacture, valued at 13,000,000*l.*, and we have a total of 14,700,000*l.*, and with 20 per cent. for distribution, 17,600,000*l.*, or in the proportion of 0·32*d.* as a gross, and 0·27*d.* as a net expenditure per head per day.

[1] The production of wool in the United Kingdom has been estimated as follows:—

				lbs.
Leicestershire sheep	12,933,000 fleeces at	7lbs. each	.	90,531,000
Downs	6,130,000 „	4lbs. „	.	24,520,000
Cheviots	4,368,000 „	3lbs. „	.	13,104,000
Blackfaced	5,100,000 „	2¾lbs. „	.	14,027,750
Welsh and Irish . .	6,000,000 „	2lbs. „	.	12,000,000
				154,182,750 lbs.

Boots and Shoes, Hats, &c.

Boots and shoes constitute an expensive and necessary article of dress. Their cost at 8*s.* 6*d.* per pair would be 14,800,000*l.* Of gloves, the home production is small. In 1880 there were imported 17,469,000 pairs, valued at 1,742,000*l.* There were also imported 463,000*l.* worth of artificial flowers, and seal-skins to the value of 623,000*l.* Sealskin jackets are a great luxury. The import price in 1880 averaged 19·08*s.* per skin, and it is not uncommon for such jackets to be sold for 40*l.* and 50*l.* On hats, the amount expended may be taken at 2,000,000*l.*, making a total for these articles of 19,600,000, and with 20 per cent. for distribution 23,500,000*l.*, or in the proportion of 0·44*d.* as a gross, and 0·39*d.* as a net expenditure per head per day.

Gold and Silver Plate.

There is further the expenditure on gold and silver. According to Mr. Giffen's evidence before the House of Commons' Committee on hall-marks, about four and a half million ounces of silver are annually used in the United Kingdom for manufacture. At 4*s.* 6*d.* per oz. that would represent little more than 1,000,000*l.*, but in the manufacture of the precious metals the cost of workmanship is greatly in excess of the value of the raw material. Taking an average of 1*l.* per oz., the total amount expended would be 4,500,000*l.* The amount expended in gold plate and jewellery must be considerable, but there is no means to estimate the same. The expenditure of the precious metals differs considerably in years of commercial prosperity and years of commercial depression. Therefore it can scarcely be considered a constant in the expenditure of the people; nevertheless it may be safely estimated that upwards of 5,000,000*l.* are yearly expended in gold and silver plate, to say nothing of diamonds. Allowing 20 per cent. for distribution the expenditure would be in the proportion of 0·09*d.* gross, and 0·07*d.* net per head per day.

Total Expenditure in Dress.

The amount spent in ordinary articles of dress is as follows:—

	Gross Expenditure £	Net Expenditure £
Cotton	31,000,000	25,800,000
Wool	63,000,000	52,800,000
Linen	7,700,000	6,400,000
Silk	17,600,000	14,700,000
Leather, Felt, &c.	23,500,000	19,600,000
Gold and Silver Plate	5,000,000	4,000,000
	£147,800,000	£123,300,000

Dividing the expenditure among the entire population, the proportion is 2·75*d.* per day for the gross and 2·30*d.* per day for the net, as follows:—

	Gross *d.*	Net *d.*
Cotton	0·58	0·48
Wool	1·18	0·98
Linen	0·14	0·11
Silk	0·32	0·27
Boots, Gloves, &c.	0·44	0·39
Gold and Silver Plate	0·09	0·07
	2·75*d.*	2·30*d.*

House Expenditure.

House-rent.

After food and clothing comes house-rent. The amount charged to duty on dwelling-houses in 1878–9 was 36,609,000*l.*, and the annual value of dwelling-houses not liable to duty under 20*l.* was 32,692,000*l.*, making a total of 69,301,000*l.* Adding one-fifth to the amount charged with inhabited house duty, 8,000,000*l.*, in order to obtain the real amount of rent, the total amount so expended is 77,000,000*l.*, equal to 1·44*d.* per head per day. Assuming house property to return 6 per cent., the net cost would be about 72,500,000*l.*, giving a proportion of 1·36*d.* per day per head.

Furniture.

To house-rent we must add the expense for furniture. The number of houses built yearly averages 60,000. At 100*l.* furniture each the expense of furnishing them would be 6,000,000*l.* But existing houses require constant additions and renewal. The total number of houses is now 6,500,000,[1] and the total rental may be estimated at 100,000,000*l.* Let only 5 per cent. on the amount of rental be taken for renewal of furniture and the amount is 5,000,000*l.*, making a total, with the furniture of new houses, of 11,000,000*l.* Deduct from this 20 per cent. for distribution, and the expenditure is 0·20*d.* gross, and 0·16*d.* net per head per day.

Coal.

The consumption of coal for household purposes was given by the Royal Commissioners in 1869 at 18,000,000 tons. Assuming the present consumption at 20,000,000 tons, its value at 12*s.* per ton wholesale, and 15*s.* retail, would be 12,000,000*l.* and 15,000,000*l.* respectively, or at the rate of 0·29*d.* as the gross, and 0·22*d.* as the net cost per head per day.

Gas.

We have no account of the total expenditure on gas and other descriptions of light, such as paraffin, tallow, stearine and wax candles, &c., all over the kingdom. The total amount of gas-rate (private lights), received by the Metropolitan Gas Companies is about 3,000,000*l.*, representing an expenditure of 16*s.* per head. Taking 10*s.* a head for the whole urban population and 5*s.* a head for the rural, the whole expenditure would be 13,700,000*l.* Deducting 20 per cent. for distribution, and the amount is 11,000,000*l.*, or in the proportion of 0·25*d.* as the gross, and 0·20*d.* as the net expenditure per day for every individual.

Water.

No data exist for estimating the expenditure for water. Here also the expenditure in cities is greatly in excess of the expenditure in rural districts, whilst considerable quantities of water are used for manu-

[1] The Census Commissioners reported the number of houses inhabited in 1881 to be as follows:—

England and Wales	4,833,844
Scotland	729,010
Ireland	912,261
	6,475,115

facturing purposes. The total amount received for water rate by the Metropolitan Water Companies is about 1,400,000*l.* a year, which gives a proportion of 7*s.* 3*d.* per head. Assuming only 5*s.* per head on 20,000,000 of urban population the expenditure would be 5,000,000*l.*, or 4,000,000*l.* net, or in the proportion of 0·09*d.* as the gross, and 0·07*d.* as the net expenditure per day per head.

Total House Expenditure.

The total expenditure connected with the dwelling-houses of the population would appear to be as follows:—

	Gross Expenditure £	Net Expenditure £
House-rent	77,000,000	72,500,000
Furniture	11,000,000	9,000,000
Coal	15,000,000	12,000,000
Gas	13,700,000	11,000,000
Water	5,000,000	4,000,000
	£121,700,000	£108,500,000

The proportion being 2·27*d.* per head per day among the whole population as the gross expenditure, and 2·01*d.* as the net, viz.:—

	Gross *d.*	Net *d.*
House-rent	1·44	1·36
Furniture	0·20	0·16
Coal	0·29	0·22
Gas	0·25	0·20
Water	0·09	0·07
	2·27*d.*	2·01*d.*

Tobacco.

Another branch of expenditure is tobacco, extensively consumed and highly taxed. In the year ended March 31, 1880, the quantity of tobacco entered for home consumption was, unmanufactured, 48,191,000 lbs.; manufactured cigars, 1,150,000 lbs.; other sorts, 153,000 lbs.; valued at 2,877,000*l.*; and the amount of duty was 8,783,554*l.*, making a total of 11,661,000*l.* Add 20 per cent. to the quantity of unmanufactured tobacco for other ingredients used in the process of manufacture, and calculate the whole at 4*s.* 6*d.* per lb. for tobacco and 12*s.* per lb. for foreign manufacture, and the amount paid will be 13,176,000*l.*, the proportion being 0·24*d.* as the gross, and 0·05*d.* as the net expenditure per head per day for each individual.

Education and Church.

Education.

The expenditure on education is partly of a public and partly of a private character. The income for elementary education in the year 1879–80 was, in England and Wales, 5,078,000*l.*; Scotland, 848,000*l.*; and Ireland, 772,000*l.* Total, 6,698,000*l.* This amount, representing the cost of 3,590,000 children in attendance in the three kingdoms, is in the proportion of 1*l.* 17*s.* per child. Taking the Public Elementary Schools to cover three-fourths of the children of school age, there are at least 900,000 children not included in the above, which, at 3*l.* per pupil, will give 2,700,000*l.* To these there must be added the income of the Grammar and other Endowed Schools, given by the Commissioners at

336,000*l.*; of the Public Schools, 65,000*l.*; the income of the Universities, estimated at 1,000,000*l.*; and the public grants for Science Art Museums, amounting to 580,000*l.*, making a total expenditure on education of upwards of 11,000,000*l.*, only a fifth of which probably is on material, viz., 2,200,000*l.*, or 0·20*d.* gross and 0·04*d.* net per head per day.

Literature, Science, and Art.

The number of books published during the year, including new books and new editions, as given in the 'Publishers' Circular,' in the five years from 1875 to 1879, averaged 5,200. Taking only 500 copies per book and 4*s.* per volume, the amount would be 7,200,000*l.* Probably 5,000,000*l.* is a safe amount to take as the annual expenditure. The expenditure for Science includes the subscriptions to scientific societies, the maintenance of private observatories and museums, schools, &c. The Art Exhibitions, and the high prices given for painting, sculpture, &c., show that a considerable amount is expended in the same. The total thus expended under this head may be calculated at 7,000,000*l.* gross, or 5,000,000*l.* net, or in the proportion of 0·13*d.* gross and 0·09*d.* net per head per day.

Newspapers.

Another important branch of expenditure eminently educational is the daily newspaper. In 1854 the number of stamps impressed on newspapers in the United Kingdom was 122,178,000. Since then, however, the stamp duty and the advertisement duty alike have been abolished, and the penny paper has been started with marvellous success. Taking the daily issue at 4,000,000, the cost to the public would be 5,000,000*l.* gross and 3,500,000*l.* net, or in the proportion of 0·09*d.* gross and 0·06*d.* net per head per day.

Church.

Of considerable importance as respects the amount is the expenditure for ecclesiastical purposes. In 1871 there were in the United Kingdom 62,950 clergymen and others connected with religious offices. Taking the number now at 75,000 and their average income at 150*l.* per year, the total would be 11,125,000*l.*, a large portion—fully a half, however—derived from tithes and other endowments, and only about five millions as expended from annual income. In 1851 there were in England and Wales 31,000 places of worship of all denominations. At this moment in the United Kingdom there must be at least 50,000. Assuming only 200*l.* for expense of maintenance, caretaking, insurance, &c., the amount is 10,000,000*l.*; in this case also about the half being provided by endowments. Besides this there is the amount contributed for missionary purposes, given in 1880 at 1,700,000*l.* Altogether the amount expended for ecclesiastical purposes out of the annual income may be taken at 12,000,000*l.*, but only one-fifth of the amount as expenditure apart from salaries, viz., 2,400,000*l.*, or at the proportion of 0·23*d.* gross and 0·04*d.* net, per head per day.

AMUSEMENTS.

Theatres and Music Halls.

Lastly, there is the amount expended in amusements of all kinds. First in importance is the theatre. In 1877 Mr. Hollingshead gave in evidence that in London there were forty-five theatres licensed by the Lord Chamberlain, and six licensed by the magistrates, with a nightly holding capacity of 76,000, being on an average of twenty per 1,000 inhabitants. Assuming theatrical provision on the same proportion among the 20,000,000 of urban population, there would be provision of 400,000, and at 1*s.* 6*d.* each for 200 nights, the total sum would be 6,000,000*l.* The 'Era Almanac' gives a list of about 276 theatres, and this, at an average capacity of 1,400, would give an aggregate capacity of 386,000. The London theatres are considerably larger. Of music-halls the number given in the 'Era' is 216. Taking their average capacity at 400 and at 6*d.* per night, also for 250 nights, the sum so expended would be about 500,000*l.*, making, with the theatrical, an expenditure of 6,500,000*l.*, only one-fourth of which, viz., 1,600,000*l.*, is spent in materials, or in the proportion of 0·12*d.* gross and 0·03*d.* net per head per day.

Other Amusements.

The Crystal Palace is a type of another order of amusements. By the courtesy of the manager, Major Page, we learn that the average number of visitors who paid for admission in the three years, 1878 to 1880, was 988,760, of whom 833,728 were adults, and 155,032 children, besides nearly as many of season-ticket holders, performers, and others. The ordinary receipts of the Company from admissions in 1880 were 40,000*l.*, and the amount received from reserved seats and programmes 20,604*l.*, making a total of 60,600*l.*, giving an average of about 1*s.* 3*d.* per person. Add 1*s.* 6*d.* for the railway and 6*d.* for refreshment in excess of the cost at home, we may assume that every visitor pays at least 3*s.* 3*d.* There are, however, special days—Boxing Day and Easter Monday, and two other Bank holidays, or equivalent days in the manufacturing districts, in all four days in the year—when a large portion of the population is in quest of amusement. On one such day in London 120,000 find their way to the Crystal and Alexandra Palaces, 72,000 to the different Galleries, and 95,000 to the Zoological, and Horticultural, and Kew Gardens. Assuming that on such days one in ten of the urban population, or about 2,000,000, is bent on amusement, and that on an average 3*s.* per head is the amount expended, the total for each day would be 300,000*l.*, or for the four days 1,200,000*l.*[1] But there are amusements of quite another order. How shall we estimate the expense incurred on the Derby day or on racing all the year. There are about 2,500 race-horses, the breeding and training of which cost 300*l.* each, or 750,000*l.* The amount spent in a month's grouse-shooting by a single party is put down at least at 447*l.* Fox-hunting is another heavy source of expenditure. There are 150 packs of fox-hounds kept in England and Wales, the aggregate cost of which, including the cost of hunters, is put down at 700,000*l.* Then there is fishing, coursing, cricket, archery, bicycling,[2]

[1] The weekly railway receipts indicate the effect of a holiday on the movements of the people. Taking the entire passengers' receipts of the Great Eastern, Great Northern, Great Western, London and Brighton, London, Chatham, and Dover, London and South-Western, Midland, and London and North-Western for the week before, and the week after the Bank holidays in 1880, the excess of receipts amounted to 260,000*l.*, but as many take their holiday before the actual day, and many return after the same, the account is not exact. The average receipts per annum for the last three years for traffic to the Crystal Palace by the London, Brighton, and South Coast Railway were 25,655*l.* On Easter Monday the receipts were 1,084*l.*; on Whit Monday 1,022*l.*; on the August Bank Holiday 790*l.*, and on Boxing Day 466*l.*

[2] The Secretary of the Bicycle Union informs us that 100,000 may be taken as the number of machines in use, entailing an annual expense of about 500,000*l.*, besides the expense of subscription to clubs, uniforms, repairs, and many more items.

and numerous other sports, all involving a large expenditure. A total of 6,000,000*l.* a year, of which about one-fourth, or 1,500,000*l.*, is spent in materials, or a proportion of 0·11*d.* gross, and 0·02*d.* net per head per day, will probably cover all the other forms of amusements in the United Kingdom.

Taxes.

To the personal expenditure thus traced we should add the amount paid to the State and expended by the same, as well as the amount paid to the local government. In the year ended March 31, 1880, the amount paid in customs, excise stamps and duties, land tax, house duty and property and income tax, amounted to 67,826,000*l.* Of this 44,626,000*l.* have already appeared in the personal expenditure for food and drink. There remains, therefore, to be added 23,200,000*l.* of public taxation, while for local purposes the amount levied direct by rates in 1873–74, was 24,332,000*l.*, making a total of 47,532,000*l.* Of the 92,158,000*l.*, thus levied by taxes (public and local), by far the largest portion is expended in salaries in the United Kingdom. What may be considered as nationally expended are votes for supply, manufacture, and repair of warlike and other stores, 1,200,000*l.*; superintending establishment of, and expenditure for, works, buildings, and repairs, at home and abroad, 850,000*l.*; dockyards and naval yards, at home and abroad, 1,300,000*l.*; naval stores, 1,000,000*l.*; new works building, 550,000*l.*; public works, 1,500,000*l.*; Foreign and Colonial Civil Services 567,000*l.*; in all 6,967,000*l.* The proportion being 0·89*d.* gross, and 0·13*d.* net per head per day.

Cost and Profits of Distribution.

In order to arrive at the real expenditure, we have deducted 20 per cent. from retail prices for the cost and profits of distribution, as well as all taxes imposed on articles of food and drink. The real cost and profits of distribution should, however, be calculated as adding to the utilities of the articles consumed. The amount deducted for distribution being 155,000,000*l.*, the half representing the real cost is 77,500,000*l.*, which gives a proportion of 1·45*d.* per head per day.

Summing up the different items of expenditure, incomplete as I fear they must be, they are as follows:—

Total Expenditure.

	Gross Expenditure		Net Expenditure	
	£	per cent.	£	per cent.
Food and Drink	500,400,000	56·9	349,200,000	51·0
Dress	147,800,000	16·8	123,300,000	18·0
House, Coal, Gas, Water	121,700,000	13·9	108,500,000	15·9
Tobacco	13,100,000	1·5	3,000,000	·4
Education	11,000,000	1·3	2,200,000	·3
Literature, Science, and Art	7,000,000	·8	5,000,000	·7
Newspapers	5,000,000	·6	3,500,000	·5
Church	12,000,000	1·4	2,400,000	·4
Theatres and Music Halls	6,500,000	·7	1,600,000	·2
Other Amusements	6,000,000	7	1,500,000	·2
Taxes	47,500,000	5·4	7,000,000	1·0
Cost of Distribution	—	—	77,500,000	11·4
Total	878,000,000	100·0	684,700,000	100·0

These two sums give an average expenditure per day per head of 16·63*d.* as the personal, and 12·71*d.* as the real or national expenditure, or 25*l.* per annum in the one case, and 19*l.* in the other.

Balance of Income and Expenditure.

Comparing now these amounts with the personal and national income the results are as follows:—

	£
Income	915,000,000
Expenditure	685,000,000
Excess	230,000,000

The excess of annual income appears very large, but the result arrived at by a method altogether different approaches very nearly that of Mr. Giffen by the capitalisation at different times of the different sources of income.

The different items of expenditure above enumerated are far, indeed, from exhaustive. The important items of domestic service, medical attendance, carriage and horses, travelling by railway and steamboat, by omnibus and tramway,[1] and charity, would each and all amount to large sums. But the greater part of such expenditure remains in the country, and consists of a simple transfer from hand to hand, having but little influence on the main question of the national expenditure.

The expenditure of the people might be classified into expenditure abroad and expenditure at home, expenditure in materials, expenditure in wages, and expenditure for the necessaries of life and for luxuries. Without attempting any further analysis, and having regard to the facts above stated, in connection especially with what has been recently brought out by the Census, of a continuously increasing population—the effect of an increasing birth-rate and a decreasing death-rate—we may conclude that the present appropriation of wages and other income cannot be said to be opposed to the economic progress of the people of the United Kingdom. A minute examination of the different items of expenditure is, indeed, calculated to remove the impression of any great extravagance on the part of the people as a whole. A large expenditure in bread, meat, woollen goods, and house-rent is a most economical expenditure. An expenditure of 124,000,000*l.* on alcoholic drinks is certainly very large, but reduced to the real expenditure the sum total is 42,000,000*l.* There is one element, however, which does not appear from this calculation, which might prove most unsatisfactory if properly inquired into, and it is that the averages arrived at are, in many cases, the mean of two extremes—the extreme of waste and the extreme of penury; for side by side with those living in luxury and having no thought of waste, there are large numbers whose conditions of nourishment, state of dwelling-houses and clothing, are of the lowest character. Nothing is gained by exaggerated statements of the national loss arising from the wasteful consumption of this or that article, or by taking as a national loss that which is in effect nothing more than the transfer of money from one to another; but a proper regard to the right expenditure of money is of the highest importance to the individual and to the nation, for waste and profligacy are the parent of pauperism, de-

[1] In the year ended June 30, 1880, as many as 173,067,103 passengers were conveyed by tramways, and the amount received from passengers was 1,308,114*l.*

moralisation, and declension. And no greater service can be rendered by the economist or philanthropist than by exhibiting the duty and importance of husbanding aright our resources, and making them conducive to the economic progress of the nation.

The Committee is fully aware that some of the deductions and reasonings in this report are not founded upon well-ascertained facts, nevertheless it deemed it useful to present them as materials for consideration, and as helps to the elucidation of a subject of the highest social and economic importance. The report points out many wants and desiderata, and the Committee recommends the reappointment of the Committee, with an increased number of members, for the purpose of suggesting means for supplying the same on a uniform and scientific basis.

Total Expenditure.

	Gross Expenditure	Per head per day	Per cent.	Net Expenditure	Per head per day	Per cent.
Articles of Food and Drink:—	£	*d.*		£	*d.*	
Bread	77,500,000	1·41	8·8	60,000,000	1·12	8·8
Potatoes	33,200,000	·64	3·7	27,700,000	·51	4·0
Vegetables	17,000,000	·32	1·9	14,000,000	·25	2·0
Meat	99,800,000	1·87	11·4	83,000,000	1·55	12·1
Fish	14,500,000	·26	1·7	11,700,000	·23	1·7
Butter and Cheese	36,000,000	·67	4·1	30,000,000	·56	4·4
Milk and Eggs	42,000,000	·78	4·8	35,000,000	·66	5·1
Fruit	11,100,000	·19	1·3	9,300,000	·17	1·4
Sugar	27,000,000	·50	3·0	24,700,000	·46	3·6
Tea	15,300,000	·60	1·8	8,800,000	·16	1·3
Coffee	3,000,000	·05	·3	2,200,000	·04	0·3
Beer	75,000,000	1·40	8·5	29,000,000	·54	4·2
Spirits	40,000,000	·75	4·6	8,000,000	·14	1·2
Wine	9,000,000	·16	1·0	5,800,000	·10	0·9
Articles of Dress:—						
Cotton	31,000,000	·58	3·5	25,800,000	·48	3·8
Wool	63,000,000	1·18	7·2	52,800,000	·98	7·7
Linen	7,700,000	·14	·9	6,400,000	·11	·9
Silk	17,600,000	·32	2·0	14,700,000	·27	2·1
Leather	23,500,000	·44	2·7	19,600,000	·39	2·9
Gold and Silver Plate	5,000,000	·09	·5	4,000,000	·07	·6
House Expenditure:—						
House-rent	77,000,000	1·44	8·8	72,500,000	1·36	10·6
Furniture	11,000,000	·20	1·2	9,000,000	·16	1·3
Coal	15,000,000	·29	1·7	12,000,000	·22	1·8
Gas	13,700,000	·25	1·6	11,000,000	·20	1·6
Water	5,000,000	·09	·6	4,000,000	·07	·6
Tobacco	13,100,000	·24	1·9	3,000,000	·05	·4
Education	11,000,000	·20	1·3	2,200,000	·04	·3
Literature, Science, and Art	7,000,000	·13	·7	5,000,000	·09	·7
Newspapers	5,000,000	·09	·5	3,500,000	·06	·5
Church	12,000,000	·23	1·3	2,400,000	·04	·4
Theatres and Music Halls	6,500,000	·12	·7	1,600,000	·03	·2
Other Amusements	6,000,000	·23	·6	1,500,000	·02	·2
Taxes	47,500,000	·89	5·4	7,000,000	·13	1·2
Cost of Distribution	—	—	—	77,500,000	1·45	11·2
Totals	878,000,000	16·63	100	684,700,000	12·71	100

Report of a Committee, consisting of JAMES GLAISHER, *F.R.S., F.R.A.S.*, E. J. LOWE, *F.R.S.*, Professor R. S. BALL, *F.R.S.*, Dr. WALTER FLIGHT, *F.G.S., and* Professor A. S. HERSCHEL, *M.A., F.R.A.S., on Observations of Luminous Meteors during the year* 1880–81.

OF regular systematic observations of luminous meteors during the past year, the Committee has very few particulars to report. The expected passage of the earth, at the end of November last, through the cluster or train of meteors circulating in the orbit of Biela's comet, proved to be only a source of disappointment, as no marked abundance of Andromedes during the last week of November 1880 was anywhere noticed by observers. But a somewhat unusual display of the Leonids on the morning of November 14 was recorded in America, and the descriptions of the shower were corroborated by observations of numerous bright Leonids at Moncalieri, near Turin, on the same meteoric date. The existence of a sensible cluster in the stream following the principal one, about thirteen years later in its encounter with the earth, and of another preceding the main group at about the same interval, is shown by Professor Kirkwood from past appearances of the November meteors to be pretty satisfactorily established.

A considerable display of the quadrantids of the 1st–3rd of January was also noted by Mr. Denning at Bristol on the morning of January 2, 1880, showing that periods of especial brightness of this shower, like those of the other annual displays, are features of its appearance which would certainly reward observers' close attention.

Of the Geminids and Lyrids no notable returns were recorded during the past year, and the extreme brightness of full-moon light prevented the August Perseids from exhibiting any unusual appearance. At the few places where a sufficiently clear sky enabled observers to be on the watch for them, the annual meteor shower on August 10, 1881, seemed to be, in point of frequency and brightness, of an exceptionally meagre and inconspicuous description.

Notices of occasional fire-balls and bright meteors have been recorded and published from time to time during the past year. But these announcements not having been immediately followed up by timely inquiries for similar accounts from other quarters, have furnished little of very weighty importance to describe. A few real paths have been deduced; but of these and of the miscellaneous observations of shooting-stars and fire-balls that have been collected during the past few years, more leisure would be needed for reduction and description than passing circumstances of the Committee's labours have allowed it to bestow upon them. A careful review and attentive comparison of the materials, however, will yet, it may be hoped, enable the Committee to offer at a future time, by their arrangement and discussion, some astronomical deductions and conclusions of more enduring interest and consequence than the promiscuous chronicle of ephemeral phenomena which at present constitutes the unassorted accumulation of the past few years meteor-records.

In an appendix of much value subjoined to this Report (Appendix I.), Dr. Walter Flight relates the recent occurrences of stone-falls and discoveries of meteoric irons, and reviews the mineralogical examinations to which they have been submitted. Besides the new mineral chromium-sulphide, or daubréelite, Dr. Laurence Smith has now observed the occurrence of chromite in nodules—an entirely new character of metallic irons—in the iron meteorites of Cohahuila. The structure of meteoric irons themselves is undergoing microscopical examination, and evidence of the strongest kind is furnished by the inspection that in many of them solidification must have proceeded in the quietest conditions, with crystallisation of perfect symmetry and regularity throughout their mass. Three recent stone-falls are recorded—on November 4, 1879, early in May 1880, and on March 14, 1881—in India, Persia, and in England.

Of the last aërolite, which weighed about three and a-half pounds, the descent in our own country is one of special interest to the present meeting of the British Association, which celebrates its fiftieth gathering in the county and city of its birth, at York, from the meteorite having quite recently fallen in that county. A fuller account of this stone-fall, and of the aërolite itself, than that given by Dr. Flight is, from examinations of the circumstances connected with it by Professor Herschel, added in another appendix of this Report. Although no analysis of the stone has yet been made, it appears, by comparison with other aërolites in the collection of the British Museum, conducted with a specimen presented by the North-Eastern Railway Company to the National Mineralogical Collection, to be of the ordinary grey chondritic class, a class of the commonest type of aërolites, which comprises in itself at least four-fifths of all the iron and stone masses which have actually been seen to fall. This recent accession, therefore, to the globe's geological constituents, furnishes another instance of the prevailing uniformity of meteoritic substance, and of its never-failing conformity, in the great majority of aërolites, to a well-marked mineralogical description which distinguishes them very strikingly from ordinary terrestrial rocks. The Middlesbrough aërolite is also remarkable in its outward form by the unusual distinctness of the deep grooves and furrows with which it is indented by heat and attrition of the air, on that rounded side or low summit of the stone which must evidently have been constantly presented foremost to the action of the resisting fiery atmosphere which impeded the aërolite's motion in its suddenly arrested course.

Appendix I.

On Aërolites and Detonating Meteors. By Dr. Walter Flight.

The (Butcher) Meteoric Irons of Cohahuila.[1]

A year or two ago attention was directed to the discovery by Dr. L. Smith of daubréelite in one of these irons. He has since met with a nodule of chromite in the interior of compact iron from one of these masses. His attention was attracted to an enclosed nodule, the lustre of which was less vitreous than that of the chromium sulphide: it was virtually a black granular mass. When heated with strong nitric acid in the water-bath, not the slightest impression was made upon it, thus showing that it is not daubréelite. Heating it in fused sodium carbonate in no way

[1] See *Amer. Jour. Sc.* ii. November 1871, and xvi. 1878, 270. Also these Reports, vol. for 1879, p. 125. (Appendix of Report on Luminous Meteors, by Dr. Flight.)

affected its non-solubility in acids. 150 milligrammes of the finely pulverised mineral was fused with ten times its weight of sodium bisulphate, and was attacked but not dissolved. Subsequent treatment with sodium carbonate and nitre broke it up, and the results of the analysis were:—

Chromium oxide	62·71
Iron protoxide	33·83
	96·54

While chromite has been known to be associated with meteorites, this is the first instance of its having been found embedded in this manner in the interior of meteoric iron.

Some of the particles of chromite, when placed in a very intense light, were found to be feebly translucent, and to have a dark reddish-purple colour. This observation, it appears, had already been made by M. Stanislaus Meunier, of Paris.

1840.—*De Calb Co., Caryfort, Tennessee.*[1]

Brezina points out that in Tschermak's Catalogue[2] this iron is described as compact, and in Rose's 'Beschreibung und Eintheilung' it is shown to resemble that from Babb's Mill. A fine section, acquired from Professor L. Smith, shows it to be rightly placed near the irons of Arva and Sarepta. Almost every band of kamacite, 1·5 to 3 millimètres across, carries a bar of porous schreibersite; band-iron and interstitial iron are sparsely present, and of a dull grey colour. Two enclosed pieces of troilite, from 3 to 4 mm. diameter, are surrounded by schreibersite from 1·5 to 2 mm. thick, and around this is an irregular shell of beam-iron.

1853.—*Tazewell, Claiborne Co., Tennessee.*[3]

Brezina points out that in the Catalogue prepared by Tschermak[4] this iron is indicated as *Of*, showing fine-ruled Widmanstättian figures. It differs, however, very much from other irons of this group, like that from Lion River, Jewell Hill, Charlotte, &c., while it closely resembles the Butler iron (see below). While, however, in the latter case the chief walls of the skeleton enclose very large chambers, here they are very small, so that the skeleton-character is far less marked. The characteristic of the two irons of Butler and Tazewell rests mainly on the very unusual smallness of the octahedral lamellæ, whereby the beam-iron, or its representative, almost vanishes, the irons consisting almost entirely of interstitial and band-iron (and of troilite enclosed in both, and schreibersite plates in Tazewell). Whether the almost infinitely thin nucleus of the lamellæ is identical with the ordinary beam-iron can only be decided by further investigation. The appearance of traces of granular structure renders it very probable.

1873.—*Chulafinee, Cleberne Co., Alabama.*[5]

The writer refers to a mass of iron which was found in 1873, and supposed at the time to be a specimen of bog iron-ore. It was taken to a

[1] A. Brezina, *Sitzber. Akad. Wiss.* 1880, lxxxii. Oct.-Heft.
[2] *Mineralog. Mitth.* for 1872, 165.
[3] A. Brezina, *Sitzber. Akad. Wiss.* 1880, lxxxii. Oct.-Heft.
[4] *Mineralog. Mitth.* for 1872, 165.
[5] W. E. Hidden, *Amer. Jour. Sc.* 1880, xix. 370.

blacksmith, who managed to remove a piece weighing $3\frac{1}{4}$ lbs., which was wrought into horse-shoe nails and a point for a plough. It remained where it was found till last year, when it was sent to Menlo Park. It weighs $32\frac{1}{2}$ lbs., and its form, as well as the character of an etched surface, are shown in woodcuts accompanying the paper. An analysis shows it to contain iron and nickel, with a little copper, phosphorus, and carbon. It is being made in duplicate, and will be published later on. The Widmanstättian figures are well developed.

1875.—*Butler, Bates Co., Missouri.*[1]

This iron has already been described by Broadhead[2] and Smith,[3] the latter finding it remarkable for the very large and regular Widmanstättian figures which it displays. A specimen, weighing 1 kilogramme, 334 grammes, acquired by the Vienna Collection from Dr. L. Smith, was found to have three etched surfaces nearly perpendicular to each other. It was noticed that the greater part of the iron had an even dull appearance, but in this lustreless iron-grey part lay numerous—in part individual, in part irregularly cohering lamellæ, of which four differently directed systems appear on the sections. The lamellæ together form an octahedral skeleton, just as in Tschermak's schematic figure 5[4] the crystal-structure of iron is shown to exhibit a hexahedral skeleton.

The ground-mass, though lustreless and structureless, shows a peculiar play of light, to which later reference will be made; its hardness is remarkably low—a little below 4—being distinctly scratched by fluorite. The nuclei of the lamellæ are purely granular, and in several respects show the greatest resemblance to the ground-mass (in hardness, &c.); only a few exhibit feebly in their broader parts a granular structure like what the beam-iron of other irons presents. The lamellæ are covered with band-iron (tänite) which is recognised by its high lustre and pale isabel-yellow colour; they are very small, the nucleus and its two covers being in few cases more than 1-60th of a millimètre broad, and the length usually 15 to 20 mm. (some are 30 mm.) When lamellæ differently directed come together, one system is usually developed quite complete, as if produced before the other; sometimes, though rarely, nucleus springs from nucleus and cover from cover, in proof of the simultaneous origin of the two systems.

From the main structure of the four systems, not only parallel, but also, in sparing quantities, irregularly orientated small plates intersect the ground-mass. To microscopically minute substructures of them is due the peculiar play of light of that part of the iron. Troilite occurs in rounded or lenticular masses, some 2 centimètres in diameter, but none is found in the lamellated systems.

The largest of the sections does not vary very much (about 13°) from the position of a leucitohedral face; three distinctly marked lamellar systems cross it at angles of 70°, 61°, and 49°. For the face (533) the corresponding values are

$$65{\cdot}4°, 0°, 65{\cdot}4°, 49{\cdot}2° \quad (0° + 65{\cdot}4°) = 65{\cdot}4°.$$

The drawings of these sections are to be published later on.

[1] A. Brezina, *Sitzber. Akad. Wiss.* 1880. lxxxii. Oct.-Heft.
[2] Broadhead, *Amer. Journ. Sc.* [3] x. 401.
[3] Smith, *Amer. Journ. Sc.* [3] xiii. 211.
[4] Tschermak, *Sitzber. Akad. Wiss.* lxx. 1874, 443.

1877.—*Casey County, Georgia.*[1]

A fragment of this iron in the Vienna Collection is stated by the writer to exhibit broad and very regular Widmanstättian figures. The beam-iron averages 2 mm. across; this iron is almost exclusively developed, with unusually sharp lines of etching. Band and interstitial iron are only present in traces, and schreibersite and troilite are not recognisable.

1878.—*Whitfield County, Georgia.*[2]

A fragment in the shape of a wedge was found to exhibit Widmanstättian figures of average size, which in certain places by the massive development of schreibersite were broken through: the band-iron is of average breadth, the interstitial iron distinguished by its unusual dark colour. In many places the magnetite fills partings which penetrate from the natural surface to a depth of 2 to 3 centimètres into the iron.

1879, *November 4th.*—*Kalumbi, Wayee (Wai, Jaluca), Sattara, Presidency of Bombay, India.*[3]

Brezina records the presentation to the Vienna Collection of a piece of a meteorite weighing 165 grammes by Mr. M. Wood, of the Bombay Branch of the Royal Asiatic Society. The fall occurred at the above place and date, and the stone has the form of a four-sided wedge, with a nearly square base. Its weight is $10\frac{1}{4}$ lbs. and 197 grains, and its density is 3·45. According to an incomplete analysis 58·75 per cent. was insoluble in hydrogen-chloride (consisting of silicates, and the silicic acid of the decomposed portion), and, in addition, there was iron oxide, or rather iron protoxide with alumina 27·62, nickel 1·56, lime 0·83, and magnesia 11·88 per cent. The meteorite resembles Forsyth, has a bright yellowish ground-mass; the chondra are firmly enclosed in the ground-mass, and for the most part white and felspathic. This stone is to be classed with the white chondrites.

1880 (*early in*).—*Colorado Basin, Ivanpah, Southern California.*[4]

This block of iron was found in the Colorado Basin, within eight miles of Ivanpah, which is about 200 miles north-east of San Bernardino in Southern California, by a Mr. Goddard, who while crossing a *wash* had his attention arrested by a singular-looking boulder. The block is oval in shape, having a side somewhat flattened; its surface is covered with depressions and dents, as if it had been pelted all over with pebbles while soft or plàstic. These concavities are from 1 to 4 inches across, and, in addition, there are three round holes an inch deep, as if made by the little finger. The mass is supposed to weigh 120 lbs., and it is 14 inches long, 9 inches broad, and 7 inches deep. The examination of a fragment shows it to be highly crystalline, requiring no etching to reveal the Widmanstättian figures; the cleavage appears to be octahedral. The schreibersite is very thin, and, according to Shepard, of two kinds: one in flat leaves, the other in wavy semi-cylinders or irregular prisms; the latter, he says,

[1] A. Brezina, *Sitzber. Akad. Wiss.* 1880, lxxxii. Oct.-Heft.
[2] *Ibid.* [3] *Ibid.*
[4] C. U. Shepard, *Amer. Jour. Sc.* 1880. xix. 381.

may be the rhabdite of Reichenbach. The density of the iron is 7·65 and its composition:

Iron	94·98
Nickel	4·52
Phosphorus	0·07
Graphite	0·10
	99·67

1880, *May (first half of)*.—*Karand*, 12 *miles east of Teheran, Persia.*[1]

'The fall of a meteorite which was actually seen, and which is not an event of every-day occurrence, deserves, on account of its mineralogical interest, some slight notice. It is not possible here to ascertain with certainty the constituent minerals; it is therefore possible at present only to give a short sketch of the stone; later on, when we have the material to work with and the help of an authority in this branch, we may return to the subject. In the first half of the month of May last year, 1880, we were called before the Shah, who handed to us a metallic shining mineral, weighing about 400 grammes, which, from the outer crust still adhering to it, we at once recognised as a meteorite. We saw that the Shah took the shining metal in it for silver, for he asked the value of it. But when we spoke of the iron, and its probably containing nickel, and that the mineral had more scientific than intrinsic worth, it was permitted to us to take the stone away, and to break off a piece for closer examination.

'The Shah made himself acquainted with the origin and cause of meteorites, and informed us that the stone in question weighed 45 kilogrammes, and fell in the neighbourhood of the village of Karand, twelve miles east of Teheran, with an explosive noise like thunder.

'Half of the stone was covered with a thin, blackish, fused crust, while the fresh lustrous fractured surface showed it to have formed a portion of a much larger stone. A fragment weighing 3·66 grammes was found to possess a density of 4·36. The fractured surface showed a grey, passing into green, ground-structure, with, in places, single pieces of an oil-green mineral, with a lustre of glass, probably olivine. In the mass lay, closely strewn together, small and large granules of white iron; also little plates of this metal lay enclosed in it, and violet-blue tinted grains, similar in their play of colour to copper pyrites.

'The pulverised mineral is pretty light, and almost entirely soluble in hydrochloric acid. The fractured surface was covered in a few days with a thin oxidised crust, although some portions of it are as fresh after five months as at first.'

1880. *Found in May.*—*Lexington County, South Carolina.*[2]

A mass of iron, weighing 10½ lbs., was found at this locality, in May, and sent to the Shepards, father and son, for examination. It has the form of a cylinder with two flattened edges; the surface is nearly free from yellow hydrated peroxide of iron, being mostly enveloped with a black and brittle coating, which, though containing some troilite, is yet almost entirely formed of magnetite. Amygdaloidal masses of troilite, of

[1] Mining engineer Ferd. Dietzsch, in Teheran; in a paper intituled 'Geologisches Berg- und Hüttenmännisches aus Persien,' in *Berg- und Huettenmännische Zeitung*, March 18, 1881.

[2] C. U. Shepard, *Amer. Jour. Sc.* 1881, xxi. 117.

the size of filberts, are met with. Magnetite and graphitoid are found coating the troilite. The Lexington iron closely resembles the Bohumilitz iron, found in 1829, and preserved at Prague, especially in the two etched surfaces: they, in fact, are the only two which strikingly show the *moirée métallique* lustre; the crystalline bars in the Lexington iron are nearly twice as large as those in the Bohemian specimen. The included spaces are filled with extremely minute lines of tänite, crossing each other at all angles from 90° to 150°. Its density is 7; that of homogeneous fragments being 7·405, and that of the troilite 4·77. Analysis showed it to consist of:

Iron	92·416
Nickel	6·077
Cobalt	0·927
Insoluble matters	0·264
Tin	a trace
Phosphorus	a trace
	99·684

1881, *March* 14, 3.35 *p.m.—Pennyman's Siding, Middlesbrough, Yorkshire.*[1]

My friend, the esteemed Secretary of our Committee, has drawn attention to the fall of a meteoric stone, near Middlesbrough, during the early months of this year. The day was bright, the air calm, and the sun shining when it fell, about 19 yards from the signal-box and 48 from the spot where two or three men were standing, and when picked out of the hole which it had made in the ground it was still warm. He writes: 'It is a beautifully perfect meteorite, of a low pyramidal or shell-like shape, measuring about 5 inches by 6, and about 3 inches high, and it weighs $3\frac{1}{2}$ lbs. The grey tufaceous stone, of which it consists internally, is, as usual, completely glazed over, or enveloped in a thin black molten crust, which hides from the eye its true stony character, the latter being only visible here and there at its grazed edges.'

A portion has been sent to the British Museum for analysis. With the exception of this little piece removed, the almost undisfigured meteorite was shown at York in the Museum of Scientific Objects at the jubilee meeting of the British Association. It is now deposited in the York Philosophical Society's Geological Museum.

Appendix II.

On the Fall of an Aërolite near Middlesbrough, Yorkshire, on March 14, 1881. *By* A. S. Herschel, *M.A., F.R.A.S.*

The meteoritic stone-fall recorded in this paper took place at 3.35 p.m., on a clear and bright, but rather cold and windy, afternoon in March last, on a part of the North-Eastern Railway Company's branch-line from Middlesbrough to Guisbrough, at a point where a short siding and signal-box upon the line, established in connection with some brick-fields adjoining it, are known from them by the name of Pennyman's Siding. The place is about a mile and three quarters from Middlesbrough along the Guisbrough branch line, and a few miles on the

[1] A. S. Herschel, *Newcastle Daily Chronicle*, March 30, 1881, Newcastle-on-Tyne.

Middlesbrough side of the first station on the line at Ormsby. The fall was witnessed by the permanent-way inspector, W. Ellinor, and three platelayers engaged in repairing a switch-heel at the siding; it was first announced to them by a whizzing or rushing noise in the air, followed in a second or two by a sudden blow of a body striking the ground not far from them. A little search revealed the hole made by the stone at the foot of the slight embankment of the south side of the line, about forty-eight yards from the place where they had been working, and less than twenty yards from the signal-box, in which the pointsman and one of the platelayers were conversing, and the latter thought that a stone had been thrown at the building by his companions outside, to attract his attention.

The direction of the wind, which was only a light air, was from N.E.; but it was fresh at Pinchingthorpe and neighbouring places in the district, and it is, perhaps, on that account that no sound of a report in the air accompanying the fall was heard either where the stone fell or at places near it in the Guisbrough and Cleveland District, at Pinchingthorpe, Hutton-Gate, Guisbrough, Maske, Saltburn, and Redcar, where information on this point was requested from the station-masters of the railway by one of the North-Eastern Railway Company's engineers of the Darlington District, Mr. W. Cudworth.

On the other hand, information sought and collected by Mr. W. R. Smithson, of Northallerton, in the north-eastern part of Yorkshire, proved that a considerable detonation was perceived, both at Northallerton and four miles east of Northallerton (by himself; eighteen miles S.S.W. from Middlesbrough), and also at Welbury, twelve miles from Middlesbrough in the same direction, and at Chopgate in Bidsdale, among the Cleveland Hills, about ten miles S.S.E. from the place of fall. These scanty indications point apparently to a direction of the meteor's flight, if it was not quite vertical, from some quarter in the south. But the direction of the wind may have led to the distant audibility of the sound in the south-west, and not in other parts of Yorkshire near the place of fall.

At all these points the sound resembled the boom of a gun, or of a gunpowder or boiler explosion in the distance, so loud as to be likened to thunder at Northallerton, the furthest known point at which it was heard. At Welbury, twelve miles from Middlesbrough, on the railway between that town and Northallerton, some platelayers heard it, and described it as sufficiently forcible to shake the earth and a rail upon which one of them was seated. It was not a solitary bounce, but a concussion, followed by a soughing sound, and then by a second crash, resembling the tipping of stones, or like an echo from rocks or woods when a gun is fired. The direction of the first boom was, like that recorded at the other places by proper compass measurements, in the direction of Middlesbrough. But the following crash is described as coming from a different quarter, from the east, or south-east, at Welbury, and it may either have been an echo of the original sound among the Cleveland hills, a few miles east of Welbury, or perhaps an indication of an earlier part of the meteor's course over the region of those hills due south from Middlesbrough, before the final stoppage of its flight.

Neither at the place of fall, nor at any other point of observation where accounts were furnished, do any luminous or cloud-forming phenomena of the fire-ball's passage in the air seem to have been seen, notwithstanding the clear brightness of the sky which was everywhere reported to have prevailed. Combining this negative evidence with the moderate description of the atmospheric concussion which the accounts of the report convey, it seems most probable that the direction of the fire-ball's descending course through the rarest strata of the atmosphere must have been nearly vertical, so as to escape general observation in the beaming sunshine by its great altitude overhead. The almost exactly vertical direction of the hole pierced in the earth by the stone's penetration through the coke-ballast of the railway-slope affords evidence of the same general directional character with what is indicated by the aërial phenomena which have been described.

The stone was warm—'new milk warm'—when felt with the hand at the bottom of the hole by the platelayer who found it a few minutes after the fall. It was extracted, without injury or disturbance of the hole, with the hand; and after the first surprise at the occurrence, it was left on a ballast heap, and a communication of the circumstances, and consignment of the stone, were made next day by Mr. Ellinor to the Railway Engineer, Mr. W. Cudworth, who was passing on the line. Immediate care of the meteorite was taken by Mr. Cudworth, who took those steps for its preservation which have secured its present exhibition in the collection of the York Museum, and who by his subsequent efforts collected most of the local information on the stone-fall which it has been the immediate object of this paper to describe.

The weight of the meteorite as found was about 3lbs. $8\frac{1}{4}$ozs.; and its entirely fused and crusted surface has scarcely suffered any visible abrasions by the fall and extraction from the earth. It is a slightly scolloped or conchoidal-looking, low pyramid, of between five and six inches width in the two dimensions of its base, and about three inches high. The rounded summit and sloping sides are scored and grooved, with a polish like black-lead, in waving furrows running to the base, showing that this side was foremost during the whole of the fusing action of the atmosphere which the meteorite underwent in its flight. The rear, or base, is equally fused and branded by heat, but rough, dull brown in colour, and not scored or furrowed. From the size of the hole which it pierced, it must have struck the earth front-foremost, and have turned edgewise finally on nearing the bottom of the hole. It is somewhat difficult from this circumstance to assign a real axis of the hole's direction. But the penetration-line sloped apparently about 10° from the vertical, from the S.S.E. The hole was eleven inches deep, penetrating with knife-like sharpness the surface herbage, and seven or eight inches of coke-ballast, and thereafter brick-earth or coarse clay to the remaining depth. By the courtesy of the North-Eastern Railway Company's Directors and servants, the hole has been preserved entire, enclosing it with some hundredweights of the surrounding earth *in situ* in a strong box with a sheet iron floor, which was slid under it through the yielding clay.[1]

An experiment was also made at the same time on the work of penetration of a cast-iron model of the aërolite, driven in front of a short oak pile to the same depth into the earth, at an immediately adjoining spot, by repeated falls, through about four feet, of a heavy iron drop-weight weighing 70lbs. The iron model was first driven front-foremost,

[1] The earth-chest was placed in the Museum of the York Philosophical Society during the meeting of the British Association in the city. Its unwieldy weight is now replaced there by a light plaster model taken of the surface and of the burrow-like bore-hole made by the meteorite in the earth which it contained.

and then edgewise, to the prescribed depth into the ground, for which fifty blows were found to be necessary in the first, and twenty blows in the latter form of the experiment. A mean of these may fairly be adopted as affording a pretty accurate determination of the aërolite's real energy of impact and of its work of penetration through the solid earth. This measured quantity was 9,307 ft.-lbs., and taking the stone's weight as 3lbs. 8½ozs. when it fell, it is easy to infer from this that the actual velocity of fall with which the stone struck the ground must have been 412ft. per second. As it would acquire this velocity by falling freely through 440 fathoms, or half-a-mile, while in falling freely forty miles from the highest regions of the atmosphere to the earth, it would reach the earth's surface with a velocity nine times as great as that actually observed, it is sufficiently clear how little of the original planetary speed with which it entered the atmosphere can have remained over to affect in any marked degree either the terminal velocity or the verticality of its fall. The immense opposition and resistance which the air offers to the intruder's passage, even through its upper strata, is, in fact, evident from the deep erosions, by heat and attrition together, which the aërolite's front surface has received.

A model, hand-moulded in clay, and then cast in plaster, of the meteorite, easily coloured to imitate it, with brushed black-lead on the furrowed face, and with dull brown paint upon the back, was made by Professor Herschel on the arrival of the stone at Newcastle, where the aërolite was publicly exhibited for a short time. A copy of the model was sent to the British Museum, and was there shown in the newly opened galleries of the Mineralogical Department of the Natural History Collection at South Kensington. The stone itself was also beautifully photographed in several positions by Mr. Gould, the artist-photographer of Sir William Armstrong's Ordnance Works in Newcastle-on-Tyne, and copies of these photographs and of the model were distributed to several quarters, one, at Dr. Brezina's request, being sent with a small specimen of the stone to the Vienna Imperial Mineralogical Museum.

Calculated from the water-displacement of the model, the stone's specific gravity is 3·15. But this estimate may be a little underrated, from a small exaggeration of the marginal outline, perhaps not entirely counteracted by opposite errors of the thickness of the model imitation. Approached to a silk-suspended magnetised needle the meteorite attracts it in all positions slightly, showing a uniform distribution through it of a sensible quantity of metallic iron, which, however, usually imparts to ordinary stony aërolites a rather higher average specific gravity than that above concluded from the model's water-displacement.

Having decided upon its appearance at York in the approaching exhibition of objects of scientific interest, formed to assist the British Association in celebrating in that city its fiftieth annual meeting, the Board of Directors of the North-Eastern Railway Company appointed a Committee to arrange for the immediate section and analysis of the aërolite. An angle was sawn off from the back by a skilled lapidary, weighing about 50 grammes, and large enough to afford a thin microscopic section, which was produced; and the resulting fragments of the operation were, after some unavoidable delays, placed with the microscopic section in the hands of the Keeper, Mr. Fletcher, and the mineralogists, Dr. Walter Flight and Mr. T. Davies, of the Mineralogical Department of the British Museum, as presents from its possessors of original fragments of the stone to the National Collection, and for ultimate examination and analysis.

The interior of the Middlesbrough aërolite exhibits a perfectly uniform structure and greyish-white appearance, spangled with frequent metallic iron-grains and crystals of iron-sulphide. A few isolated spherules of white homogeneous material, apparently identical with the cementing substance of the mass, and as large as hemp-seeds, occur at intervals, but these well-formed 'chondra,' as they are termed, appear in this aërolite to be rather large than very plentiful.

Round some of the iron-grains oxidation has caused russet-brown coloration of the neighbouring white mineral, in spots with which the sawn face and broken surfaces are all pretty freely speckled over. The ground-mass itself is a fine-grained assemblage of nearly colourless crystals cohering together pretty firmly with little intervening paste. Under the microscope a few of the larger crystals are clear and transparent, while the general aggregation of the finer ones is confused and turbid.[1] In some compacter areas, which may be paste or spherule-sections, tangled dendritic markings (perhaps indicative of the presence of manganese) spread from centres apparently of iron-grains, and by their arborescence and coralline appearance recall the recently published announcements by Dr. Hahn, of his microscopical observations of fossil forms and vestiges of organisations in the spherules of aërolites. The analysis of the Middlesbrough aërolite, which has not yet been executed, will be particularly interesting if it reveals in the metallic substance traces of manganese, and also if it succeeds in identifying the kind of silicate of which the stony substance of the meteorite seems to be almost uniformly composed. The substance in powder, as was ascertained with a very small trial of its dust, phosphoresces pretty brightly by heat when thrown on a hot iron in the dark. As this property of phosphorescent minerals, it is known, can only be restored to them after its loss by heat, either by strong and long-continued insolation or by subjecting them to strong electrical discharges, the question of the original habitat, and of the original separation or ejection of meteorites from foreign planets, suns, or comets will perhaps be narrowed in some measure by observations of this property in other meteorites besides that of Middlesbrough, in some of which the character of phosphorescence by heat may perhaps be shown by trials to be equally distinct.

Among known stonefalls, of which specimens are preserved, the nearest congeners in date with that of Middlesbrough, are Salés (France), 1798, March (8 ?) or 12, 6 p.m., 20 lbs., 3·45 sp. gr.; Alais (France), 1806 March 15, 5 p.m., 8 + 4 lbs., W. to E., 1·70 sp. gr. (carbonaceous); Timoschin (Russia) 1807, March 13, aftn., 160 lbs., 3·64 sp. gr.; Kuleschowka (Russia), 1811, March 12, night, 13 lbs. + 9 lbs. (?), 3·49 sp. gr.;

[1] Mr. T. Davies, of the British Museum, Mineralogical Department, has quite recently obliged the Committee, in anticipation of the meteorite's chemical analysis by Dr. Flight, with some observations of its visible characters and composition. The substance of his remarks extracted from the timely communication in which he was so good as to notify them to the Committee, is added as a postscript to this account. While it renders unnecessary and superfluous some of the details which follow here of the meteorite's internal appearance, it will also be seen to correct and clear up some of the surmises offered regarding the occurrence of microscopic simulations, or 'dendrites' in the Middlesbrough aërolite, and regarding the possible astronomical connection of that aërolite with the Salés and Kuleschowka ones.

[Cutro (Calabria), 1813, March 14, stonefall and dust; ? if any specimen has been preserved.]

Comparison with the Salés and Kuleschowka stones shows a fair resemblance in the mineral type and iron-dissemination with the present meteorite, but yet sufficient diversity of character to distinguish them from each other very clearly. The solid massive Timoschin aërolite consists largely of metallic iron, and that of Alais contains it only in fine powder mixed with a clayey carbonaceous earth. The description of outward appearance is, on the contrary, exactly accordant in the Kuleschowka and Middlesbrough aërolites, although they differ in weight and size. The same low broad pyramid, or buckler-like figure, grotesquely trenched and furrowed from the rounded summit outwards in front, 'like the forehead of a bony skull'; with a black polished surface there, and dull brown crust upon the hollowed back; these are features that tell the meteorite's tale of a darting, smelting journey through the air with a clearness and distinctness which it is rare to find typified so perfectly among the known hundreds of museum specimens, as we find them shown and illustrated in the Kuleschowka stone's description, and in the excellent actual example of them which has now anew presented itself in the Middlesbrough aërolite.[1] But it is unsafe to reason, even from identical chemical composition, on possible physical connection between their courses, since such chemical identity has been pointed out by Daubrée in several instances of pairs of aërolites of such widely different dates of fall that no assignable astronomical common origin can be traced or even suspected to exist on that ground between them. The present aërolite appears also to belong to the most usually occurring ordinary chondritic class, although by simplicity of composition it will perhaps be found to take rank among some of the more exceptional meteorites of that description.

At the time of the stone's fall the constellation Perseus was overhead, and the small constellation Triangulum was a little south of the zenith at Middlesbrough. Some cometary accordances with meteor-showers proceeding from that constellation in the first two weeks of March have been noticed, to which in connection with this aërolitic date attention may be directed on account of the very near appulse which one of the comets' orbits makes to the orbit of the earth.

The comets are those of A.D. 1746, and A.D. 1231; the former approaching the earth's orbit within about one-hundredth, and the latter within about six-hundredths of the earth's distance from the sun, on March 8 and 10 respectively. The showers of shooting-stars agreeing pretty nearly with them were deduced by Mr. Denning from catalogues of meteor observations by Weiss and Schiaparelli, and are well-marked,

[1] See A. Goebel's descriptions of Russian aërolites, *Mélanges Physiques et Chimiques de l'Académie Impériale de St. Pétersbourg*, vol. vii. pp. 286–288. Instances of end-on erosion, denoting constant orientation of front- and rear-faces of aërolites in their flight, occur also in some stones of Stannern, in one of L'Aigle, and in those of Gross Divina and Goatpara, as first noticed by Von Haidinger (Vienna Academy *Sitzungsberichte*, vol. xl. pp. 525–532, 1860, and xlv. p. 790, and lix.); in that of Durala (India), depicted by Professor Maskelyne (*Philosophical Magazine*, vol. xxv. p. 440, 1863); and finally in that of Karakol (in the Kirgis Steppe, May 9, 1840) as figured by A. Goebel (*loco sup. cit.*, pp. 318–324). The last aërolite especially exhibits with exceptional perfection, almost rivalling the anterior rotundity and grooving of the Middlesbrough one, the blunt-pointed projectile configuration which denotes one-sided action of the heat-erosion.

active showers. The meteorites of Segowlee, March 6, 1853, and Sagan (Silesia), March 6, 1636, may perhaps belong, with the Middlesbrough and other meteorites named above, to the same aërolitic systems, and the directions of the courses of fireballs and shooting stars of the week from March 8 to 14, and of meteorites should they again happen in that week, will accordingly furnish very interesting materials for observation.

Note on a Preliminary Examination of the Middlesbrough Aërolite. By Mr. T. Davies, *F.G.S. Communicated to the Committee, Aug.* 30, 1881.

'I find that this aërolite bears a marked resemblance to the Kuleschowka stone in the fine grained ash-grey base with a similar distribution of the iron and the small rust-spots, which, however, are larger and more frequent in the former. The spherules are also larger and more abundant. Though belonging to the chondritic type of aërolites, I do not consider it as markedly chondritic, many of the spherules not showing such a distinct periphery in their section as would allow of the stone being classed among the more prominent instances of this group.

'With regard to its resemblance to the Kuleschowka aërolite, I find that it is equally similar (macroscopically) to other aërolites of the same type which bear very different dates of their descent; notably those of Milena, Croatia, April 26, 1842, Tourinnes la Grosse, Dec. 7, 1863, and Girgenti, Sicily, Feb. 10, 1853; so that I fear that no theory founded on coincidence of date would be of much value [either as safe guidance in searches for the evidence of a mineralogical resemblance, or as satisfactorily confirming any such a resemblance].

'From microscopic examination I should regard the stone as consisting very largely of enstatite, which exists not only in large isolated crystals but also in groups of crystals, the olivine constituent (if any) being represented by the finely crystalline ground-mass; but this is not sufficiently distinct in the section to be determined by microscopic examination only.

'The "dendrites" of the spherules and enstatite crystals, are a mere structural simulation of organisms, and are not due to manganese oxides, which, if present, would be in sufficient quantity to be easily identified chemically. All workers with the microscope are familiar with these simulations.'

Report of the Committee, consisting of Professor CAYLEY, *F.R.S.*, Professor G. G. STOKES, *F.R.S.*, Professor H. J. S. SMITH, *F.R.S.*, Professor Sir WILLIAM THOMSON, *F.R.S.*, Mr. JAMES GLAISHER, *F.R.S.*, *and* Mr. J. W. L. GLAISHER, *F.R.S.* (*Secretary*), *on Mathematical Tables.*

I. *The Factor Table for the Sixth Million.*

IN last year's report it was stated that the factor tables for the fourth and fifth millions had been published by Mr. James Glaisher, and that the factor table for the sixth million was in the press. The printing and stereotyping of this million, the last of the three millions intervening between the tables of Burckhardt and Dase, has been completed; and the volume will be published shortly.

II. *Results of the Enumeration of the Primes in the Sixth Million.*

The following table contains the chief results of the enumeration of the primes in the sixth million, arranged according to the numbers of primes in the centuries.

5,000,000 to 6,000,000.

	Number of centuries each of which contains n primes										
n	5,000,000 to 5,100,000	5,100,000 to 5,200,000	5,200,000 to 5,300,000	5,300,000 to 5,400,000	5,400,000 to 5,500,000	5,500,000 to 5,600,000	5,600,000 to 5,700,000	5,700,000 to 5,800,000	5,800,000 to 5,900,000	5,900,000 to 6,000,000	5,000,000 to 6,000,000
0	0	1	0	0	0	1	0	0	2	0	4
1	3	3	3	1	6	3	3	3	4	2	31
2	14	11	8	9	10	15	10	18	10	16	121
3	42	31	46	48	50	40	49	59	50	55	470
4	107	134	97	119	88	108	99	99	94	107	1052
5	165	161	156	160	159	166	155	151	172	152	1597
6	208	194	218	175	212	198	218	189	191	197	2000
7	165	158	183	191	194	190	184	216	200	190	1871
8	136	158	136	139	129	136	148	114	123	124	1343
9	86	79	79	91	93	83	76	81	79	81	828
10	38	49	47	44	41	35	41	47	52	47	441
11	29	13	17	14	12	17	15	15	15	21	168
12	7	5	7	7	4	7	2	6	5	6	56
13	0	3	3	1	2	1	0	2	2	1	15
14	0	0	0	1	0	0	0	0	1	1	3
	6458	6436	6493	6462	6438	6402	6404	6387	6436	6420	64,336

This table shows the number of centuries in each group of 100,000, each of which contains no prime, each of which contains one prime, two primes, &c. For example, between 5,000,000 and 5,100,000, there is no century containing no prime (*i.e.* consisting wholly of composite numbers), there are three centuries which contain one prime, fourteen which contain two primes, &c., and so on. The number at the foot of each column is the total number of primes in the group of numbers to which the column relates; thus, for example, there are 6,458 primes between 5,000,000 and 5,100,000.

The corresponding tables for the fourth and fifth millions were given on pp. 47 and 32 of the Reports for 1879 and 1880 respectively.

The next table shows the number of primes in each successive group of 10,000 between 5,000,000 and 6,000,000. Thus, for example, between 5,000,000 and 5,010,000 there are 639 primes, between 5,010,000 and 5,020,000 there are also 639 primes, between 5,020,000 and 5,030,000 there are 658 primes, and so on.

5,000,000 to 6,000,000.

	5,000,000 to 5,100,000	5,100,000 to 5,200,000	5,200,000 to 5,300,000	5,300,000 to 5,400,000	5,400,000 to 5,500,000	5,500,000 to 5,600,000	5,600,000 to 5,700,000	5,700,000 to 5,800,000	5,800,000 to 5,900,000	5,900,000 to 6,000,000
I.	639	632	659	654	630	638	633	635	654	648
II.	639	641	649	637	640	623	638	667	632	667
III.	658	655	650	643	657	633	638	632	627	649
IV.	638	660	647	649	650	667	643	632	641	646
V.	628	639	673	648	635	618	624	654	657	633
VI.	668	644	630	642	659	634	641	636	627	639
VII.	639	645	649	642	641	655	635	617	635	633
VIII.	648	631	653	653	623	636	638	637	641	636
IX.	655	641	629	654	651	641	635	637	677	644
X.	646	648	654	640	652	657	679	640	645	625
	6458	6436	6493	6462	6438	6402	6404	6387	6436	6420

The corresponding tables for the fourth and fifth millions were given on pp. 48 and 33 of the Reports for 1879 and 1880 respectively.

The following is a list of successions of composite numbers of ninety-nine and upwards occurring in the sixth million.

SEQUENCES OF 99 AND UPWARDS.

Lower Limit	Upper Limit	Sequence
5,137,547	5,137,651	103
5,178,193	5,178,301	107
5,209,177	5,209,279	101
5,211,109	5,211,209	99
5,323,949	5,324,051	101
5,398,597	5,398,697	99
5,516,281	5,516,393	111
5,518,687	5,518,817	129
5,528,287	5,528,387	99
5,577,851	5,577,959	107
5,589,019	5,589,127	107
5,673,449	5,673,557	107
5,723,899	5,723,999	99
5,826,001	5,826,127	125
5,831,401	5,831,509	107
5,837,399	5,837,501	101
5,845,193	5,845,309	115
5,888,741	5,888,873	131
5,976,079	5,976,181	101
5,982,413	5,982,523	109

This table shows that the 103 numbers between 5,137,547 and 5,137,651 are composite, and so on; the numbers in the first two columns being the primes which bound the sequences of composite numbers.

The corresponding lists of sequences for the fourth and fifth millions were given on pp. 49 and 33 of the Reports for 1879 and 1880 respectively.

III. *Results of the Enumeration of the Primes in the First Nine Millions.*

As the gap between Burckhardt's and Dase's tables is now completely filled up, it is possible to give results derived from an enumeration of primes extending without break over the first nine millions.

The following table (which is similar in arrangement to the first table in Section II.), shows the number of centuries in each of the nine millions which contain no prime, one prime, &c. The number at the foot of each column is the number of primes in the million.

0 to 9,000,000.

n	Number of centuries each of which contains n primes									
	0 to 1,000,000	1,000,000 to 2,000,000	2,000,000 to 3,000,000	3,000,000 to 4,000,000	4,000,000 to 5,000,000	5,000,000 to 6,000,000	6,000,000 to 7,000,000	7,000,000 to 8,000,000	8,000,000 to 9,000,000	0 to 9,000,000
0	0	1	1	2	2	4	6	4	4	24
1	3	16	25	30	26	31	28	30	34	223
2	29	72	97	136	161	121	173	171	178	1138
3	140	257	338	400	403	470	482	541	570	3601
4	372	667	775	862	943	1052	1049	1066	1078	7864
5	801	1253	1408	1480	1488	1597	1603	1691	1742	13063
6	1362	1743	1878	1929	1994	2000	1948	1993	1966	16813
7	1765	2032	1997	1849	1929	1871	1916	1754	1788	16901
8	1821	1612	1526	1561	1433	1343	1366	1394	1278	13334
9	1554	1182	1036	950	922	828	840	787	778	8877
10	1058	691	558	497	426	441	374	360	390	4795
11	592	311	227	221	189	168	156	155	143	2162
12	316	113	98	60	63	56	46	40	38	830
13	122	39	28	19	18	15	10	10	11	272
14	32	7	6	4	3	3	3	2	2	62
15	20	3	1	0	0	0	0	2	0	26
16	8	1	0	0	0	0	0	0	0	9
17	3	0	1	0	0	0	0	0	0	4
21	1	0	0	0	0	0	0	0	0	1
26	1	0	0	0	0	0	0	0	0	1
No. of primes	78,499	70,433	67,885	66,329	65,369	64,336	63,799	63,158	62,760	602,568

It appears from this table that the centuries with eight primes are the most numerous in the first million, the centuries with seven primes in the second and third millions, and the centuries with six primes in all the other millions.

The next table shows the number of primes in each group of 100,000 from 0 to 9,000,000, with differences.

0 to 9,000,000.

NUMBER OF PRIMES IN EACH GROUP OF 100,000.

	No. of Primes	Difference		No. of Primes	Difference
0 – 100,000	9,593		4,500,000 – 4,600,000	6,493	120
100,000 – 200,000	8,392	1201	4,600,000 – 4,700,000	6,523	– 30
200,000 – 300,000	8,013	379	4,700,000 – 4,800,000	6,475	48
300,000 – 400,000	7,863	150	4,800,000 – 4,900,000	6,554	– 79
400,000 – 500,000	7,678	185	4,900,000 – 5,000,000	6,522	32
500,000 – 600,000	7,560	118	5,000,000 – 5,100,000	6,458	64
600,000 – 700,000	7,445	115	5,100,000 – 5,200,000	6,436	22
700,000 – 800,000	7,408	37	5,200,000 – 5,300,000	6,493	– 57
800,000 – 900,000	7,323	85	5,300,000 – 5,400,000	6,462	31
900,000 – 1,000,000	7,224	99	5,400,000 – 5,500,000	6,438	24
1,000,000 – 1,100,000	7,216	8	5,500,000 – 5,600,000	6,402	36
1,100,000 – 1,200,000	7,225	– 9	5,600,000 – 5,700,000	6,404	– 2
1,200,000 – 1,300,000	7,081	144	5,700,000 – 5,800,000	6,387	17
1,300,000 – 1,400,000	7,103	– 22	5,800,000 – 5,900,000	6,436	– 49
1,400,000 – 1,500,000	7,028	75	5,900,000 – 6,000,000	6,420	16
1,500,000 – 1,600,000	6,973	55	6,000,000 – 6,100,000	6,397	23
1,600,000 – 1,700,000	7,015	– 42	6,100,000 – 6,200,000	6,402	– 5
1,700,000 – 1,800,000	6,932	83	6,200,000 – 6,300,000	6,425	– 23
1,800,000 – 1,900,000	6,957	– 25	6,300,000 – 6,400,000	6,337	88
1,900,000 – 2,000,000	6,903	54	6,400,000 – 6,500,000	6,347	– 10
2,000,000 – 2,100,000	6,874	29	6,500,000 – 6,600,000	6,402	– 55
2,100,000 – 2,200,000	6,857	17	6,600,000 – 6,700,000	6,338	64
2,200,000 – 2,300,000	6,849	8	6,700,000 – 6,800,000	6,375	– 37
2,300,000 – 2,400,000	6,791	58	6,800,000 – 6,900,000	6,411	– 36
2,400,000 – 2,500,000	6,770	21	6,900,000 – 7,000,000	6,365	46
2,500,000 – 2,600,000	6,809	– 39	7,000,000 – 7,100,000	6,369	– 4
2,600,000 – 2,700,000	6,765	44	7,100,000 – 7,200,000	6,306	63
2,700,000 – 2,800,000	6,716	49	7,200,000 – 7,300,000	6,348	– 42
2,800,000 – 2,900,000	6,746	– 30	7,300,000 – 7,400,000	6,299	49
2,900,000 – 3,000,000	6,708	38	7,400,000 – 7,500,000	6,301	– 2
3,000,000 – 3,100,000	6,676	32	7,500,000 – 7,600,000	6,305	– 4
3,100,000 – 3,200,000	6,717	– 41	7,600,000 – 7,700,000	6,347	– 42
3,200,000 – 3,300,000	6,691	26	7,700,000 – 7,800,000	6,245	102
3,300,000 – 3,400,000	6,639	52	7,800,000 – 7,900,000	6,364	– 119
3,400,000 – 3,500,000	6,611	28	7,900,000 – 8,000,000	6,274	90
3,500,000 – 3,600,000	6,575	36	8,000,000 – 8,100,000	6,250	24
3,600,000 – 3,700,000	6,671	– 96	8,100,000 – 8,200,000	6,301	– 51
3,700,000 – 3,800,000	6,590	81	8,200,000 – 8,300,000	6,283	18
3,800,000 – 3,900,000	6,624	– 34	8,300,000 – 8,400,000	6,285	– 2
3,900,000 – 4,000,000	6,535	89	8,400,000 – 8,500,000	6,245	40
4,000,000 – 4,100,000	6,628	– 93	8,500,000 – 8,600,000	6,326	– 81
4,100,000 – 4,200,000	6,540	88	8,600,000 – 8,700,000	6,281	45
4,200,000 – 4,300,000	6,510	30	8,700,000 – 8,800,000	6,299	– 18
4,300,000 – 4,400,000	6,511	– 1	8,800,000 – 8,900,000	6,220	79
4,400,000 – 4,500,000	6,613	– 102	8,900,000 – 9,000,000	6,270	– 50

The numbers of primes in each quarter-million in the first nine millions, with differences, are :—

0 to 9,000,000.

NUMBER OF PRIMES IN EACH GROUP OF 250,000.

	Number of Primes	Difference
0 – 250,000	22,045	
250,000 – 500,000	19,494	2,551
500,000 – 750,000	18,700	794
750,000 – 1,000,000	18,260	440
1,000,000 – 1,250,000	17,971	289
1,250,000 – 1,500,000	17,682	289
1,500,000 – 1,750,000	17,455	227
1,750,000 – 2,000,000	17,325	130
2,000,000 – 2,250,000	17,150	175
2,250,000 – 2,500,000	16,991	159
2,500,000 – 2,750,000	16,922	69
2,750,000 – 3,000,000	16,822	100
3,000,000 – 3,250,000	16,761	61
3,250,000 – 3,500,000	16,573	188
3,500,000 – 3,750,000	16,566	7
3,750,000 – 4,000,000	16,429	137
4,000,000 – 4,250,000	16,437	– 8
4,250,000 – 4,500,000	16,365	72
4,500,000 – 4,750,000	16,271	94
4,750,000 – 5,000,000	16,296	– 25
5,000,000 – 5,250,000	16,172	124
5,250,000 – 5,500,000	16,115	57
5,500,000 – 5,750,000	16,026	89
5,750,000 – 6,000,000	16,023	3
6,000,000 – 6,250,000	15,967	56
6,250,000 – 6,500,000	15,941	26
6,500,000 – 6,750,000	15,950	– 9
6,750,000 – 7,000,000	15,941	9
7,000,000 – 7,250,000	15,851	90
7,250,000 – 7,500,000	15,772	79
7,500,000 – 7,750,000	15,768	4
7,750,000 – 8,000,000	15,767	1
8,000,000 – 8,250,000	15,712	55
8,250,000 – 8,500,000	15,652	60
8,500,000 – 8,750,000	15,746	– 94
8,750,000 – 9,000,000	15,650	96

and the numbers for the complete millions are :—

	Number of Primes	Difference
First million	78,499	
Second "	70,433	8,066
Third "	67,885	2,548
Fourth "	66,329	1,556
Fifth "	65,369	960
Sixth "	64,336	1,033
Seventh "	63,799	537
Eighth "	63,158	641
Ninth "	62,760	398

The following list gives the two longest successions of composite numbers met with in each of the nine millions:—

	Lower Limit	Upper Limit	Sequence
First million	370,261	370,373	111
	492,113	492,227	113
Second "	1,357,201	1,357,333	131
	1,561,919	1,562,051	131
Third "	2,010,733	2,010,881	147
	2,898,239	2,898,359	119
Fourth "	3,826,019	3,826,157	137
	3,933,599	3,933,731	131
Fifth "	4,652,353	4,652,507	153
	4,738,651	4,738,777	125
Sixth "	5,518,687	5,518,817	129
	5,888,741	5,888,873	131
Seventh "	6,034,247	6,034,393	145
	6,571,401	6,371,537	135
Eighth "	7,230,331	7,230,479	147
	7,621,259	7,621,399	139
Ninth "	8,421,251	8,421,403	151
	8,917,523	8,917,663	139

The portions of the preceding tables which relate to the first five millions were given also in last year's Report (pp. 34–36).

It may be remarked that the first table in Section I. shows that there are twenty-four centuries in the nine millions which contain no prime, and that the distribution of these centuries among the millions is:—

First million	None	Sixth million	4
Second "	1	Seventh "	6
Third "	1	Eighth "	4
Fourth "	2	Ninth "	4
Fifth "	2		

The first number of each of these centuries, which consist therefore wholly of composite numbers, is given in the following list:—

1,671,800	5,837,400	7,129,900
2,637,800	5,845,200	7,565,200
3,117,300	6,012,900	7,803,500
3,933,600	6,085,000	7,826,900
4,640,600	6,333,800	8,027,700
4,652,400	6,376,200	8,367,400
5,178,200	6,789,800	8,421,300
5,518,700	6,958,700	8,905,200

Seventh Report of the Committee, consisting of Professor E. Hull, the Rev. H. W. Crosskey, Captain Douglas Galton, Mr. James Glaisher, Professor G. A. Lebour, Mr. W. Molyneux, Mr. G. H. Morton, Mr. W. Pengelly, Professor J. Prestwich, Mr. J. Plant, Mr. James Parker, Mr. I. Roberts, Mr. S. Stooke, Mr. G. J. Symons, Mr. W. Whitaker, *and* Mr. C. E. De Rance (*Reporter*), *appointed for the purpose of investigating the Circulation of the Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations of England, and the Quality and Quantity of the Water supplied to Towns and Districts from these formations.*

The Committee had hoped in this, the seventh year of its existence, to have completed the inquiry with which it was entrusted; but, owing partly to the considerable development of works to obtain water from underground sources at the present time, and partly from the absence from England of some of its members, it has been found necessary to defer the final report on the water-bearing capabilities of the Triassic and Jurassic formations of England and Wales until next year, when the Committee also hope to present their first report on the nature of the quantity and the quality of the *other* permeable formations of the country.

River Basins of the North-East of England.

No Permian, Triassic, or Jurassic rocks occur in the basins of the Tweed, Alyn, Coquet, Wansbeck, Blyth, or Tyne.

These formations occupy the following areas, in the basins specified, as defined on the Ordnance Survey Catchment basin map.

	Magnesian Limestone	Triassic rocks	Oolites
River Wear	42	—	—
Catchment Basin, XXI.	17	—	—
River Tees	130	130	—
„ Esk	—	—	183
	189	130	183

From the investigations that have been made as to the capacity of the *Magnesian Limestone* for absorption, it appears that 10 inches of rainfall is annually available in this formation, or 400,000 gallons daily per square mile, giving a total of 73 million gallons, or a supply for a population of $2\frac{1}{2}$ millions, at 30 gallons per head.

In the *Oolitic area*, probably not more than 5 inches annually can be relied on, or 200,000 gallons per square mile, or a supply sufficient for $1\frac{1}{4}$ million people, the total underground being capable of supplying $3\frac{3}{4}$ millions of people.

The actual population in this group of river-basins is under 1,400,000, so that the supply in the area from these formations alone is more than double the demand.

The *Triassic* rocks in this area are not available for water-supply, on a larger scale; for though certain wells of no great depth, or importance, obtain fresh water, the deep borings of Messrs. Bolckow and Vaughans, and Messrs. Bell Brothers, prove the existence of rock-salt in this formation, which renders it valueless for water-supply purposes.

Professor G. A. Lebour states, for water-supply purposes it does not appear necessary to notice any of the subdivisions generally recognised in the Magnesian Limestone above the marl slate.

The following is the series, divided in such a way as appears useful for the purposes of the Committee:—

1. Yellow Sands: Generally a loose, incoherent, coarse sand with more or less calcareous cement, often concretionary, sometimes solid. Very irregular in thickness, from 60 feet downwards, and sometimes absent. Generally with a large amount of water.
2. Magnesian Limestone: Similar to No. 4, seldom more than a few feet (6 to 10) in thickness. Not always present.
3. Marl Slate: Generally a compact, flaggy, dark grey, thinly-bedded horizon, seldom more than a yard in thickness, generally impervious calcareous and sandy shale, often forming a fish-bed.
4. Magnesian Limestone: Concretionary, brecciated, compact, and cellular, fossiliferous and unfossiliferous, soft, and earthy in places, eminently hard and crystalline in others.

Unconformity.

Red Sandstone (with coal-plants): Of Upper Coal-measure age.

Professor Lebour has prepared a map of the Durham Coal-field on which the out-crop of the Permian seriès is shown, as well as the position of all sinkings and borings that have been put through the Permian to the Coal-measures, giving the thickness of the Yellow Sand and (where known) the yield of water of that division and of the overlying beds.

At Middlesbrough—Messrs. Bolckow and Vaughans'.

	feet
DRIFT	58
Sandstone and Marls	1148
Rock Salt	100
Limestone	1
Conglomerate	7
	1314

Messrs. Bell Brothers', 1874.

	feet
DRIFT	77
Sandstone, Marls, with Gypsum	1050
Rock Salt	102
Soft Rock	32
Grey Limestone	67
Gypsum and *Rock Salt*	27
	1355

The beds belong to the Keuper Marls, Waterstones, Lower Mottled Sandstone, and Permian.

The Pebble-Beds and Upper Mottled Sandstone are absent.

River Basins of the Humber Group.

North-Eastern Group.

	Magnesian Limestone	Triassic rocks	Oolites
Catchment Basin, XXXVII.	—	—	57
„ „ XL.	—	—	—
River Hull	—	—	—
„ Foulness	—	72	8

Information obtained by Mr. Whitaker through Mr. Fox Strangways:

1. Scarborough Waterworks well, near Osgodby, marked upon Geological Survey Map, Yorkshire, Sheet 94. **1a.** October 1870. Not deepened since. **2.** About 160 feet. **3.** Ninety-one feet deep, 10 feet diameter shaft measured from surface; 136 feet deep, 6 inches diameter bore-hole, measured from surface. **3a.** Three driftings total length 70 yards. **4.** Pumping always goes on; level varies according to season and speed of pumps. **4a.** About 70 feet below top, but varied, and no full record kept. **5.** From 600,000 to 800,000 gallons in twenty-four hours. **6.** Water-level varies according to season: high after wet weather, low after dry weather. **7.** Heavy rain in the district tends to raise the level, but time not noted. **8.** Analysis below. No marked peculiarity. **9.** Section of well showing all information obtained was sent to Mr. Fox Strangways in March 1875. **10.** To some slight extent. Yes. **11.** Entirely, by brick lining backed by puddle. **12.** No. **13.** No. **14.** No. **15.** No.

Scarborough Waterworks.

Analysis of Well at Osgodby.

	Grains per gallon
Carbonate of Lime	10·150
Carbonate of Magnesia	3·129
Sulphate of Lime	3·038
Chloride of Sodium	1·869
Chloride of Calcium	1·792
Silica	·294
Alumina and Oxide of Iron	·126
Organic matter	·280
Nitric Acid	a trace.
Grains of solid matter in a gallon	20·678

Hardness on Clark's Scale.

Before boiling	11°
After boiling half an hour	5°

Humber Central Group.

River Derwent	—	—	57
„ Ouse	50	500	42
Rivers Aire and Calder	44	96	—
River Don	55	120	—
	149	788	164

Of these areas the Magnesian Limestone would afford water for a population of nearly 2 millions.

The New Red area consists largely of Keuper Marls overlying Triassic Sandstones, but the area of absorption is limited to the outcrop of the Sandstone only, the water absorbed by which passes down the dip under the Marls. The available area is about 200 square miles, absorbing daily 8 million gallons, or a supply for a population of $2\frac{1}{2}$ millions.

The Oolites, at 5 inches of annual percolation, could supply about 1 million gallons.

The population in this group of river-basins amounts to nearly 3 millions, requiring a supply of 90 millions of gallons of water daily.

It has been thought desirable to recapitulate the facts obtained regarding the conditions of underground water-supply in the district of York. The basin of the Humber may be divided geologically into four divisions, all of which strike magnetic north and south, or a little west of north. The western belt consists of the Yorkshire coal-field, dipping east towards the German Ocean, and overlain unconformably by the second belt, consisting of the Permian and Trias, in which are no less than two unconformities, the Bunter overlapping the Permians, and the Keuper the Bunter.

The Oolites constitute the third belt and the Cretaceous rocks the fourth. The overlap at the base of the latter is so great that between Market Weighton and the Derwent, south of Malton, the Cretaceous rests directly on the Lias, and the Oolites form no part of the surface of the ground between those points.

In the west, the *Humber basin* is bounded by the great Pennine watershed, traversing England from north to south; to the south it is limited by the remarkable watershed which, traversing England diagonally, practically separates all the rocks below the Lias from those above it. To the north, it is terminated by the east and west watershed, crossing England from St. Bees' Head to Robin Hood Bay, north of Scarborough.

The Pebble Beds of the New Red Sandstone have been bored into at various points, between Nottingham, Retford, and Selby, and are directly overlain by the Keuper Waterstones, the Upper Mottled Sandstone and Keuper conglomerate being alike absent.

North of Selby the Pebble Beds also have thinned out, and the Keuper Waterstones and the Lower Mottled Sandstone are alone available for underground water-supply in the plains of York.

The Selby waterworks yield a water of 8 deg. of hardness, 250,000 gallons per day rising from a 6-inch hole 330 feet deep, to a height of 4 feet from the surface, or 16 feet above mean-tide level. The upper portion of the boring consists of Warp-clay and silt, the lower 262½ feet of Red Sandstone.

Borings at York, 104 feet deep, and at Market Weighton, 300 feet, did not penetrate the Keuper marls.

A well at Walmgate Bar, York, passed through

	ft.	in.	
Clay and Stone	24	0	Drifts.
Quicksand	60	0	
Fine Sandstone	204	0	Lower Mottled Sandstone.
Parting with water	0	2	
Fine Sandstone	279	0	
	567	2	

Humber Southern Group.

	Magnesian Limestone	Permian Sandstone	Triassic Sandstone	Keuper Marls	Oolites
River Trent	174	108	829	1562	12
River Ancholme	—	—	—	—	171

In this group the Magnesian Limestone would probably yield a daily average supply of 69 million gallons of water.

The population in the group is 2¼ millions, requiring 67 million gallons of water per day.

Fen Streams.

	Keuper Marls	Oolites	
River Witham	6	797	
„ Welland	0	580	Drift covered.
„ Nen	0	927	
„ Ouse	0	1316	
	6	3620	

Population of this group in 1881 was about 1¼ millions.

East-Anglian streams do not drain any Triassic or Permian strata on the surface.

Thames Basin.

Contains 931 square miles of Oolitic strata.

Cirencester.—From Messrs. Bowly & Son, sunk and communicated by Messrs. Legrand and Sutcliff to Mr. Whitaker.

	ft.
Gravel	12
Sand	2
Brown clay	1½
Forest marble [must include other oolitic beds]	114
	129½

Hants Basin.

River Avon	18	square miles of Oolite.
„ Stour	120	

Population of this group about 1 million.

West of England Streams.

	Trias	Keuper Marls	Oolites
River Basin CLV.	—	—	54
„ Bridg	—	—	12
„ Brit	—	—	24
„ Axe	24	—	6
Basin CL.	—	3	—
River Otter	30	22	—
„ Exe	252	—	—
Basin CCI.	9	—	—
River Teign	31	—	—
„ Dart	2	—	—

The Severn Basin :—Bristol Channel Group.

	Trias	K. Marls	Oolites
Basin CXLII.	4	—	—
„ CXLIII.	13	—	—
River Parret	34	94	62
„ Cary	—	70	—
„ Brul	—	35	50
„ Axe	—	64	2
„ Yeo	—	98	—
„ Avon	—	140	560

Flowing underground into Hants Basin.

	square miles
From the River Parret	62
„ „ „ Exe	52
„ „ „ Avon	220
	334

Flowing underground into the Thames Basin.

	square miles
From the Severn	94
„ „ Bristol Avon	340
	434

Clifton, near Rugby.—For Mr. Müntz. Sunk, and communicated by Messrs. Legrand & Sutcliff to Mr. Whitaker.

	feet
Sand	3
Blue clay	19½
Clay and sand	2½
Light blue clay	7
Dark blue clay	37
Clay and sand	5

	feet
Light blue clay and sand	4
Light blue clay	27
Dark blue clay	19
Clay and sand	4
Dark clay	4
	132

The Severn Basin.

	Permian	Trias S.	T. Marls	Oolites
Lower Severn	—	—	23	90
Avon (Upper)	34	8	320	4
Central Severn	—	—	—	—
Upper Severn	—	—	—	—
Wye	—	6	—	—
Ely	—	59	—	—

South Wales Streams.

	Trias	
River Ogmore	7	square miles.
„ Afon	5	
	12	

The South Wales streams draining into the Bristol Channel, are inhabited by a population of about half a million, requiring 15 million gallons of water daily.

The West Wales river basins, from St. David's Head in Pembrokeshire to Carmel's Point, Anglesea, drain an area composed entirely of impermeable rocks, and contain a population of about 180,000, distributed in the coast counties from Pembroke to Anglesea.

The North Wales river basins from Carmel's Point to the Point of Air, are inhabited by about 175,000 people, requiring $5\frac{1}{4}$ millions of gallons daily.

Following the river-basins from west to east, the Clwyd is the first that contains any Triassic rocks, occupying about 71 square miles of this area. From the thick covering of Boulder clay, probably not more than 30 is available, as an area of absorption; the rainfall of the area is small, and the quantity available not more than 5 inches per annum, or 200,000 gallons per square mile, or an average of 6,000,000 gallons per day over the available area.

River Basins of the N.W. of England.

	Permian	Triassic Sandstone	Marls
River Dee	22	279	?
West Cheshire streams	—	$145\frac{3}{4}$	10
River Weaver	3	12	$485\frac{1}{4}$
„ Mersey	$24\frac{1}{2}$	220	97
„ Irwell	107	$28\frac{3}{4}$	—
Liverpool streams	—	33	—
River Alt	—	86	—
„ Douglas	1	41	?
Basin XLV.	—	—	7
River Ribble	2	83	—
„ Wyre	18	—	110
„ Lune	2	—	—
„ Leven	2	—	—
Basin XXXII.	8	—	—
„ XXXI.	3	—	—
River Esk	20	—	—
„ Mite	9	—	—
„ Calder	13	—	—
„ Ehen	22	—	—

The population in this group of rivers amounts to nearly $4\frac{1}{2}$ millions, requiring a daily supply of no less than 135 millions of gallons of water.

Boring for salt at Fleetwood, 1881. Collected by Mr. C. E. De Rance from Mr. B. Sykes, C.E., Preston.

From surface ft.	in.			Thickness. ft.	in.
2	0	Soil		2	0
17	0	Quicksand and mud		15	0
29	6	Shingle or gravel		12	6
37	6	Blue clay		8	0
50	0	Loamy clay with sandy partings		12	6
54	4	Good yellow clay	Glacial drift, 81 feet 6 inches	4	4
82	7	Quicksand		28	3
98	1	Loamy clay with sandy partings		15	6
107	5	Strong stony marl		9	4
108	0	Boulder		0	7
131	6	Strong stony marl		23	6
137	9	White earth with red layers		6	3
141	6	Red earth		3	9
143	0	White earth with grey spar		1	6
177	8	Red earth with white spar		34	6
193	0	White earth with grey spar		15	6
344	9	Red earth with nodules and grey spar		151	9

No water was met with in the Keuper marls in this boring, nor were any brine or rock-salt beds reached. In a boring a few miles to the east, at Preesal, on the east side of the River Wyre, a boring carried into these marls had intercepted a bed of rock-salt more than 100 feet in thickness, on the surface of which brine rested. The surface of the ground is about 40 feet above the Ordnance datum-line.

In last year's Report details of a boring at Mr. Hull's brewery at Preston were given, the depth being 246 feet; the rock, pebble-beds, of the New Red Sandstone, the water rising to 65 feet above the Ordnance datum.

Two miles to the north the following well and boring have since been made by Mr. Vivian of the North of England Rock Boring Co., for Mr. Sumner, near Fulwood Lodge, Watling Street Road. Collected by Mr. C. E. De Rance from Messrs. Myers and Veevers, C.E., Preston. Surface of bore-hole 160 feet above Ordnance datum.

Depth ft.	in.	
3	0	Clay, 3 feet thickness.
7	0	Marl, 4 „ „
59	0	Sandstone (bottom of well).
72	0	Sand.
76	5	Gravel.
81	3	Sand and gravel.
84	9	Gravel.
88	6	Clay and sand.
91	10	Gravelly clay.
97	0	Clay and sand.
108	9	Sandy clay.
110	3	Grey sandstone (? boulders).
113	8	Stony clay.
114	5	Blue cobble stone (? boulder).
115	7	Stony clay.
116	1	Grey sandstone (? boulder).
120	9	Gravel and sandstone nodules.
145	6	Sand, with red sandstone fragments.
146	4	Gravel.
156	1	Red sandstone.
156	3	Red clay.
170	0	Red sandstone.
174	0	Red shale.
177	1	Red and grey sandstone.
191	10	Red shale and beds of red sandstone.
199	1	Red shale, with a little lime.
214	9	Purple shale.
215	4	Grey shaly limestone. } CARBONIFEROUS.
217	0	Blue limestone.
218	0	Light grey limy shale.
237	3	Blue shale.

East of the last boring is that made for the Fulwood Local Board by Messrs. Mather and Platt, Salford Iron Works; it was carried to 300 feet without penetrating the Pebble Beds of the New Red Sandstone. The normal height of the boring above Ordnance datum is 70 feet, or 90 feet from the surface, reduced, by pumping 40,000 gallons a day, to 20 feet above Ordnance datum.

Analysis of water from bore-hole, Fulwood, by Dr. Campbell Brown (sent to him December 28, 1880).

[Analysis expressed in parts per 100,000.]

Mark and denomination of the sample		Deep bore.
Total solid matter in solution		45·00
Organic carbon, Organic nitrogen } (By Dr. Frankland's method.)		traces only.
Ammonia		·009
Ammonia from organic matter by distillation with alkaline permanganate		·006
Nitrogen as nitrates and nitrites		·035
Combined chlorine		2·4
Hardness, temporary	9·57	
„ permanent	21·88	
„ total	31·45	

Dr. Brown states, 'This water contains a large quantity of mineral salts, especially of hardening salts. It will not be economical for washing purposes; but it is free from organic contamination, and is perfectly wholesome for drinking purposes. Most deep well waters are hard, and at the same time freer from organic matter than surface, or shallow well, water.'

Cumberland Streams, north of the Central Watershed.

	Permian	Permian Marls	Trias	Trias Marls
River Ellen	35	—	—	—
„ Waver	4	49	—	—
„ Warnpool	14	47	3	—
„ Eden	357	—	18	12
„ Lune and Esk	13	—	14	7
Total	93	96	35	19

The population of this area in 1881 is about a quarter of a million, requiring a daily supply of 7½ million gallons.

The available collecting-ground of Permian and Triassic Sandstone amounts to about 100 square miles, which, at 10 inches' percolation, would give a daily average supply of 40 million gallons, a quantity five times in excess of the requirement.

The sequence of these beds has been worked out lately by Mr. T. V. Holmes ('Q. J. G. S.' 1881), and is as follows:—

{ 1. Stanwix marls, 50 to 100 feet (unconformity).
{ 2. Kirklinton sandstones, 400 to 500 feet.

{ 3. Gypsum marls, found in borings, 600 to 700 feet.
{ 4. St. Bees' sandstone, about 1,500 feet thick under Carlisle.
{ 5. Shaly beds.

The St. Bees' Sandstone has been recently discovered, by Mr. Aveline, of the Geological Survey, to be of the same age as the Penrith, and to pass horizontally into it.

Report of the Committee, consisting of Professor DEWAR, Dr. WILLIAMSON, Dr. MARSHALL WATTS, Captain ABNEY, Mr. STONEY, Professor W. N. HARTLEY, Professor MCLEOD, Professor CAREY FOSTER, Professor A. K. HUNTINGTON, Professor EMERSON REYNOLDS, Professor REINOLD, Professor LIVEING, Lord RAYLEIGH, Dr. ARTHUR SCHUSTER, *and* Mr. W. CHANDLER ROBERTS *(Secretary), appointed for the purpose of reporting upon the present state of our Knowledge of Spectrum Analysis.*

[PLATE V.]

GENERAL METHODS OF OBSERVING AND MAPPING SPECTRA.
By W. MARSHALL WATTS, *D.Sc.*

THE best method of measuring and mapping a spectrum must, of course, depend on the object with which the spectrum is observed. If the spectroscope is employed only as an auxiliary to the ordinary methods of chemical analysis, and the object is simply to determine the presence or absence of a metal of the alkalies or alkaline earths—say lithium or calcium—very rough measurement only is needed; indeed, in most cases, the colour of the line or the general appearance of the spectrum is sufficient. But if, on the other hand, the object is, for example, the determination of the presence or absence of oxygen in the sun's atmosphere, or the description of some new spectrum observed for the first time, the case is altogether different; the greatest dispersive power that the circumstances of the case will allow must be employed, and the position of each line must be measured with the utmost accuracy attainable by the best use of the best apparatus at command.

The spectrum may, of course, be produced either by diffraction from a diffraction-grating or by refraction through a prism. The splendid diffraction-gratings furnished by Rutherford give results unapproached by any other means when the source of light is sufficiently powerful; but the intensity of a diffraction spectrum is always so much less than that of a dispersion spectrum that for most purposes of spectroscopy the prism must be employed.

For the ordinary purposes of chemical analysis, nothing can be better than a strongly-built spectroscope, provided with one prism of 60° of dense glass, and a photograph-millimetre scale, seen by reflection at the first surface of the prism.

It is not possible to construct instruments with exactly similar scales, and each instrument should therefore have its readings reduced to wave-lengths by the method of graphical interpolation, to be presently described; but it is convenient to have these reflected scales as nearly as possible similar to the one given in Bunsen's first paper.[1] On this scale the Fraunhofer lines have the following positions:—

A 17·5   B 28·9   C 35·0   D 50   E 70·9   *b* 75   F 90
G 127·3 H_1 161·2 H_2 165·7

and the Lithium, Strontium, and Thallium lines are as follows:—

Li 31·5   Sr δ 105·5   and   Tl 67·8.

[1] *Phil. Mag.* (Fourth Series) vol. xxvi. p. 247.

The brass mounting in which the scale is placed is always so made as to admit of movement horizontally, so that any division of the scale may be adjusted to any given line. The adjustment for the Bunsen scale is made by bringing the sodium line to 50 of the scale, the image of that edge of the slit which does not move when the breadth of the slit is altered being made to coincide exactly with the division 50. If this be on the left hand of the observer, then always the position of the left-hand edge of each line and band is to be observed, and in the case of a faint line the slit may be opened to admit more light, and yet an accurate reading may be obtained. This refers, of course, only to lines which are sharply defined, and not to bands of considerable breadth. The most convenient plan in making a map of an ordinary spectrum is first to put down, as exactly as possible, the positions of the well-defined lines on an ordinary lithographed millimetre scale, opening and closing the slit as convenient, and then to go over the work again, keeping the slit at one uniform width and noting the relative intensity of the lines and the width and character of the bands, whether sharply defined at the edges, or sharp at the one edge and fading away at the other, or bright in the middle and fading away at each edge. There is no better plan of noting the peculiarities of a spectrum than that employed by Bunsen, in which each bright line is represented by a black mark on the paper, whose height represents the intensity of the line.

A convenient modification of the scale used with the spectroscope for ordinary purposes has been proposed by Professor Emerson Reynolds.[1] The observing telescope carries cross wires, and as it moves from one line to another it causes an index-finger to travel round over a divided arc on a plate of opal glass, which is feebly illuminated by a small flame. The positions of the more important lines of the elements, whose spectra are easily obtained with the Bunsen flame, are marked on the opal plate; the identification of any particular element is thus made without moving the head away from the eyepiece of the instrument.

Very beautiful drawings of many of the ordinary spectra are given in Lecoq de Boisbaudran's 'Spectres Lumineux.' The means of ignition employed in producing these spectra were (1) the ordinary Bunsen flame, (2) the spark from an induction coil (without a Leyden jar) striking on the surface of the solution of the substance to be examined, (3) the spark impinging on the surface of the fused salt, (4) the spark between metallic wires. In some cases, the gas feeding the Bunsen burner was charged with hydrochloric acid gas, by making the gas pass through a flask containing a warm solution of hydrochloric acid. The spectra drawn comprise the flame-spectra of cæsium, rubidium, and potassium chlorides; barium chloride, bromide, and iodide: strontium, calcium, magnesium, manganese, copper, and gold chlorides; salts of sodium, lithium, thallium, and boracic acid; and the spark-spectra of salts of potassium, sodium, lithium, barium, strontium, calcium, magnesium, aluminium, chromium, manganese, iron, cobalt, nickel, zinc, cadmium, indium, tin, bismuth, lead, antimony, copper, silver, mercury, gold, platinum, and palladium, besides absorption-spectra of chloride of didymium, chloride of erbium, and potassium permanganate. Accurate drawings are given by Bunsen[2] of the following spectra :—Flame-spectra of potassium, cæsium, rubidium,

[1] *Phil. Mag.* (Fifth Series) vol. v. p. 106.

[2] *Pogg. Ann. der Physik u. Chemie,* clv. 366. *Phil. Mag.* (Fourth Series) vol. l. p. 527.

thallium, sodium, lithium, calcium, strontium, and barium chlorides; spark-spectra of rubidium, cæsium, thallium, sodium, lithium, calcium, strontium, barium, magnesium, erbium, yttrium, cerium, lanthanum, and didymium; and absorption-spectra of erbium nitrate and didymium sulphate.

It is necessary that the indications of each spectroscope should be reduced to the common scale of wave-lengths, if the results obtained are to be compared with those obtained with other spectroscopes: but for the mere purpose of identifying an alkali or an alkaline earth it is not necessary to go beyond the scale of the spectroscope itself. Photographed scales, giving the positions of lines directly in wave-lengths, to be used instead of the ordinary scale of equal parts, have been constructed,[1] but for accurate work it is much the best to employ a scale of equal parts, and to effect the reduction of wave-lengths separately.

It is not very often that any other means of ignition than the Bunsen flame is employed when the spectroscope is simply used as an addition to the ordinary means of chemical analysis. The employment of a higher temperature, however, much extends its range even for such purposes, and at the same time increases the difficulty of identification, and necessitates more exact measurements.

A small induction coil, actuated most conveniently by some form of battery, such as the Bichromate cell, which can be kept always ready,[2] and a small Leyden jar—the inside coating connected by an insulated wire with the one terminal of the coil, and the outside coating with the other—furnish a spark of the necessary intensity. If platinum wires are employed as poles, it is important that fresh wires should be taken each time, since wires which have been used for any particular metal often continue to give the lines of that metal with great persistency.

Bunsen[3] recommends as poles little cones of pure porous carbon, impregnated with a solution of the substance under examination. A further[4] difficulty in the employment of the spark with the spectroscope for the ordinary purposes of chemical analysis arises from the constant presence of the air-spectrum. It is necessary, therefore, to carefully map the spectrum of air[5] as obtained with the coil and spectroscope, which are to be employed, say, first with platinum wires and then with silver wires as poles. In each case the brightest lines will be those due to air, with the addition in the one case of the fine lines of platinum, and in the other of those of silver. The fine lines given by the less volatile metals are often easily distinguished from those of air by the fact that they often extend only a short distance from each pole, and do not reach across the whole breadth of the spectrum, while those of air are of equal width across the whole breadth of the spectrum.

The air-lines are fainter when no jar is employed, so that with the more volatile metals it is easier to work with the coil without a Leyden jar.

[1] *Roscoe and Schorlemmer's Chemistry*, vol. ii. pt. ii. p. 471. Salet, *Paris Chem. Soc.*, May 4, 1877.

[2] Bunsen, *Phil. Mag.* (Fourth Series), vol. l. p. 527.

[3] *Phil. Mag.* (Fourth Series), vol. l. p. 430.

[4] For other modes of procedure see Lockyer's *Studies in Spectrum Analysis*, pp. 60 and 63.

[5] Maps of the air-spectrum are given in Bunsen's paper, *Phil. Mag.* (Fourth Series), vol. l., and in Thalén's *Détermination des Longeurs d'Onde*.

The best map of the bright lines of the metals is that of Thalén[1] (upon the scale of wave-lengths), who, however, has employed poles of the metals themselves and higher coil-power than is likely to be used in ordinary laboratory work.

Other modes of ignition, which, however, will be employed for the most part only for special researches, are furnished by the oxy-hydrogen blowpipe and by the electric arc. The differences in the spectra obtained by employing these different methods of ignition may be shortly accounted for by the different temperature to which the substance is heated—at low temperatures the spectra of compounds are obtained which at higher temperatures are resolved into their elements. The Bunsen flame gives the lowest temperature, the oxy-hydrogen flame next, then the spark from a small coil without a Leyden jar; then comes the electric arc, the temperature of which increases with the number of cells employed; then the spark obtained with an induction coil and small jar, the temperature of which is increased up to the highest point obtainable by increasing the size of the coil and jar employed.

The following list of lines will be found useful in constructing the curve of wave-lengths for a one-prism spectroscope. The wave-lengths are given in tenth-metres[2] (or ten-millionths of a millimetre); there is also given the approximate position of the line on Bunsen's scale, and the reciprocal of the wave-length, or 'oscillation-frequency'—*i.e.* the number of waves in one millimetre. There are many advantages in using these 'frequencies' instead of the wave-lengths themselves, as will be afterwards explained.

(*a*) *Flame Spectra.*

	Scale-number.	Wave-length.		Oscillation-frequency.	
Lithium	31·8	6707·3		1490·9[4]	
Sodium	50·0	5896·8 5890·7	Mean 5893·7	1695·84 1697·58	Mean 1696·7
Thallium	67·8	5351·1		1868·8	
Magnesium[3]	74·5	5184·2		1928·94	
Strontium	105·5	4609·0		2169·7	

(*b*) *Fraunhofer Lines.*

	Scale-number.	Wave-length.		Oscillation-frequency.	
A	17·5	7606·1		1314·74	
B	28·9	6869·1		1455·82	
C	35·0	6563·9		1523·48	
D	50·0	5896·8 5890·7	Mean 5893·7	1695·84 1697·58	Mean 1696·7
E	70·9	5270·6		1897·31	
b_1	74·5	5184·2		1928·94	
b_2	74·8	5173·6		1932·89	
b_3 and b_4	75·0	5169·1		1934·56	
F	90·0	4862·1		2056·73	
G	127·3	4308·5		2321·02	
H_1	161·2	3969·2		2519·39	
H_2	165·7	3934·1		2541·88	

[1] *Nova Acta Reg. Soc. Sc. Upsal.*, Third Series, vi. Upsala. W. Schultz, 1868.

[2] A 'tenth-metre' is $(\frac{1}{10})^{10}$ metre.

[3] Least refrangible line of the (*b*) group, seen in the flame of burning magnesium.

[4] The lines of which the oscillation-frequency is given to two decimal places are found in Ångström's map, and in the B.A. catalogue of oscillation-frequencies; those which have only one decimal place are given on the authority of Thalén. His numbers have been corrected for the small differences between his tables and the table given in Ångström's work ('Recherches sur le spectre solaire,') p. 31, and also for the dispersion of air so as to give the wave-lengths in vacuo. All the numbers in the above table refer therefore to the vacuum.

(c) *Spark Spectra.*

	Scale-number	Wave-length	Oscillation-frequency
Cadmium	36·9	6440·1	1552·76
Lithium	44·6	6103·9	1638·37
Copper	53·2	5783·0	1729·21
Lead	58·4	5608·7	1782·9
Cadmium	66·5	5379·6	1858·9
„	68·2	5339·1	1873·0
Copper	69·9	5293·3	1889·18
„	73·1	5218·7	1916·17
„	75·6	5154·1	1940·19
„	77·8	5106·5	1958·29
Cadmium	78·7	5086·6	1966·0
Air	82·4 ⎱	5006·6	1997·4
„	82·7 ⎰	5003·6	1998·6
Barium	86·2	4934·9	2026·37
Cadmium	100·8	4678·3	2137·56
Barium	108·8	4554·8	2195·49
„	110·8	4525·7	2209·58
Calcium	135·5	4227·5	2365·44
Barium	147·1	4131·9	2420·2
Calcium	161·2	3969·2	2519·39
„	165·7	3934·1	2541·88

If the observer is not familiar with the Fraunhofer lines, or has difficulty in recognising the particular bright lines of the metals given in the preceding list, the following plan is recommended: First observe accurately the positions of the lines of the 'flame spectra' given, and from these construct an interpolation-curve; then mark on the curve the wave-lengths of the Fraunhofer lines, and so determine their positions approximately on the scale of the spectroscope. On directing the instrument to the sun or to a bright cloud, the Fraunhofer lines will certainly be found at or near these positions. Now let these Fraunhofer lines be read off as exactly as possible, and from their positions, and those of the lines of the flame-spectra, let a more accurate interpolation-curve be drawn, and let this curve be used to find the positions of the lines of the spark-spectra. The final curve should be drawn when the positions of these spark-lines have been carefully observed. If it is not convenient to make use of the spark-spectra, a very fair curve may be constructed from the lines of the flame-spectra and from the Fraunhofer lines, but a little trouble in obtaining as accurate a curve as possible will be well repaid. As a sample of what may be done with a one-prism spectroscope and reflected scale, the following numbers, taken from Lecoq de Boisbaudran, for the wave-lengths of bismuth lines, are compared with Thalén's numbers:—

Lecoq de Boisbaudran	Thalén	Lecoq de Boisbaudran	Thalén
6130	6129·0	5144	5143·5
6048	6050·0	5123	5123·5
5719	5716·5	4724	4722·0
5552	5553·0	4303	4302·0
5268	5270·0	4259	4259·5
5209	5208·0	4118	4119·0

The lines from which Lecoq de Boisbaudran's interpolation-curve was drawn are the following:—

	Scale-reading	Wave-length		Scale-reading	Wave-length
Potassium	65·55	7680	Hydrogen	83·71	6562
Solar A	72·50	7185	Cadmium	86·25	6438
Solar B	77·81	6867	Zinc	88·00	6361
Lithium	80·78	6706	Lithium	94·15	6102

	Scale-reading	Wave-length		Scale-reading	Wave-length
Sodium	100·00	5892	Cadmium	152·83	4677
Copper	103·25	5781	Strontium	157·60	4607
„	105·90	5700	Iron	174·28	4383
Lead	109·00	5607	„	180·80	4307
Silver	114·00	5464	Calcium	188·25	4226
Thallium	118·40	5349	Indium	200·83	4101
Silver	124·40	5208	Calcium	216·33	3968
Cadmium	130·03	5085	„	220·75	3933
Hydrogen	141·75	4861			

The curves of the figure illustrating this report are drawn from the same data.

The different methods of measuring the positions of the lines of a spectrum may conveniently be put into two groups, which may be called methods of consecutive coincidences, and methods of simultaneous coincidences. The chief plans employed are the following:—

'Consecutive Coincidences.'

(1) The graduated arc and vernier.
(2) The tangent-screw micrometer.
(3) The bright line micrometer.

'Simultaneous Coincidences.'

(4) The reflected scale.
(5) The double-wire micrometer eyepiece.
(6) The divided-lens micrometer.
(7) The photographic method.

It is not necessary to remark that some methods are more suitable for a small spectroscope, and others for a large one, and again, that a particular method may be employed in one case and not in another; for example, cross-wires can be employed with the solar spectrum or with any spectrum of sufficient brightness, while they are useless with very faint spectra.

A favourite plan with the opticians is that of the divided arc and vernier, in which the telescope carries cross-wires, the intersection of which is brought to coincidence first with one line, then with a second, and so on. This of course is a method of 'consecutive coincidences,' and it is a necessary condition of obtaining correct results that the collimator and slit shall remain rigidly in the same position and that the cross-wires of the telescope and the vernier shall retain the same relative position during the motion from one line to another. These conditions are attended to in the massive construction adopted by Steinheil and some other continental makers, but are fatally disregarded when the instrument is constructed of slender metal, and when the collimator and observing telescope, instead of being firmly grasped at the centre of gravity, are merely screwed by one end into a slender upright of brass, further weakened at the most important point by being attenuated into some (so-called) ornamental shape. Certain precautions must be observed in the use of a spectroscope with cross-wires to obtain good results. The eyepiece should first be removed and so adjusted that on looking through it at a sheet of white paper, the cross-wires are seen in sharp focus, then replacing the eyepiece in the observing telescope removed from the spectroscope, the telescope should be exactly focussed on a distant object. Having replaced the telescope in the instrument, the *collimator* should then be adjusted till some lines in the green—say *b* in the solar spectrum—are in accurate focus. The instrument is then in adjustment.[1] When used on the red or blue portion of the spectrum, the focus may be adjusted with the observing telescope, but the collimator should not be altered.

It is necessary that the ray to be measured should be in exact focus together with the cross-wires. If this is not the case, the ray will alter its position slightly with reference to the cross-wires, if the eye be slightly moved. The adjustment may therefore be tested by moving the eye slightly and observing whether the ray and the cross-wires move together. There is also a slight movement of the rays consequent on lateral shifting of the source of light; this is less the narrower the slit is, and the more distant the source of light is.

Some instruments are provided with a tangent-screw micrometer,—that is, a long screw, the head of which is divided into a hundred equal parts, by means of which a slow motion can be given to the observing telescope, and the number of turns of the screws, and parts of a turn necessary to carry the cross-wires from one line to another, is noted.

In the bright-line micrometer[2] the image of a fine slit in a brass plate is seen by reflexion at the first surface of the prism, and so is superposed upon the spectrum; the plate and slit have a slow motion given by a micrometer screw. This form of micrometer is specially useful with very faint spectra, when cross-wires would be useless. In observing with cross-wires a luminous spectrum the lines of which are faint, it is necessary to admit a certain amount of light into the observing telescope, sufficient to illuminate the wires (conveniently by raising an edge of the cloth used to cover up the prisms). This general light renders very faint lines invisible. In all these methods of consecutive coincidences it is necessary that no shifting of the parts of the instrument by bending or shaking, nor any disturbance of the position of the source of light, nor of the exact position of the eye, should take place during the passage of the cross-wires from one line to the next. In the methods of 'simultaneous coincidences' all these sources of error are avoided by observing at the same instant two lines—one a known line, used as a reference line, and the other the line to be measured.

The method of the reflected photographed scale, already described at some length, may be employed as a method of simultaneous coincidences, and so made more exact if, when the reading of any line is noted, care be taken to observe that the sodium-line is still exactly at 50; or if the sodium-line is not in the field, then that some other line used as reference line is exactly in its right position at the moment of observation.

The most accurate measuring instrument for use with large spectroscopes is the bifilar micrometer eyepiece. This is an eyepiece similar to those employed for astronomical purposes, provided with two crosses of fine spider-lines in the focus of the eyepiece, which must therefore be of the Ramsden construction. One of these cross-wires remains fixed; the other is moved by means of a micrometer screw. The interval between the line to be measured and a line of known wave-length can thus be determined with great precision. In taking an observation, a slight motion is given to the fixed cross-wires by means of the slow motion or tangent screw of the observing telescope, the micrometer screw of the

[1] For a different method of adjusting the collimator of a spectroscope, see a paper by Dr. Schuster, *Phil. Mag.* [5] vii. 95.

[2] *Microscopical Journal*, January 1870.

eyepiece being at the same time adjusted by the other hand, till the observer is satisfied that each line is truly coincident with the intersection of the corresponding spider-lines.

Another device for measuring the interval between two lines, quite equal in accuracy to the bifilar micrometer, is that of the divided-lens micrometer.[1] In this instrument the micrometer screw moves one-half of a lens placed just in front of the prisms, and divided along a horizontal diameter. The effect is to cause one-half of the spectrum to move along under the other half, and the sodium or any other convenient line is used as a substitute for the cross-wires, and is brought into coincidence with each of the lines to be measured. It will be seen that the necessity of admitting extraneous light to illuminate cross-wires is avoided, and this instrument can therefore be used in faint spectra with precision.

The photographic method is, of course, a method of simultaneous coincidences, inasmuch as the positions of the known lines which are employed as reference lines are recorded at the same instant as those of the unknown lines.

The bifilar or the divided-lens micrometer may have fitted to it a device for mapping the spectrum at the same time that the positions of the lines are measured. For this purpose the steel rod on which the screw of the micrometer is cut is made about three times as long, and the extra length has cut on it a much coarser thread. On this there travels a little brass piece carrying a steel point, with which a trace can be made on a slip of blackened glass. We thus obtain a mark on the blackened strip of glass corresponding to each line of the spectrum. The map so made has the defect of representing all lines, whether intense or weak, exactly alike; but it would be easy to alter it, so as to limit at pleasure the length of stroke of the tracing point. A bright line would then be denoted by a long trace, and a weak line by a short one. The same instrument might easily be made available for measuring the positions of the lines in the photograph of a spectrum, since, of course, to take a photograph of a mass of lines in a spectrum is not to have measured the wave-length of these lines, or to have determined their chemical origin.

Another instrument—very useful in measuring photographed spectra, or in drawing maps of spectra from measurements—is Beckley's spectrograph. This consists of a brass cylinder, on which the photograph is stretched, and the edge of the cylinder is graduated and provided with a vernier. There is also a straight edge, which can be brought down upon the photograph parallel to the lines of the spectrum. Each line in succession is brought up to the straight edge, and the position of the cylinder is read off by means of the vernier. The instrument is generally graduated into degrees and minutes, but it is desirable that it should carry also (on the other edge) a division into millimetres, the vernier reading to the tenth of a millimetre. The accuracy of reading is increased by substituting for the straight edge a small microscope with a 3-inch objective, and with cross-wires in the eyepiece.

We have already remarked the necessity of reducing the numbers—by whatever instrument obtained—to a uniform scale.

The scale to be employed must be applicable to all spectroscopes alike, and must be independent of the peculiar construction of the instru-

[1] *Phil. Mag.* August 1875. *Proc. Physical Society*, vol. i. p. 160.

ment—the number, position, and refracting angle of the prisms, the dispersive power of the material of which they are made, of variations in the temperature, and of all other disturbing causes. It is clear that in such a method each line can be mapped only by means of its colour, that is to say, by the length of the wave of light by which it is produced; and a spectrum so represented must be such a one as is produced by *diffraction*, and not by dispersion. Dispersion-spectra obtained by the use of prisms of different materials vary greatly in the relative breadth of the colours, so that in mapping a spectrum it is by no means sufficient to give the positions of only two or three lines as points of reference. Many otherwise valuable observations of spectra are entirely useless from the insufficient number of reference lines observed.

Three spectroscopes (each with a single prism and reflected scale), constructed by Duboscq and intended to be exactly alike, differed as shown in the following table. The numbers show the difficulty of constructing two instruments with exactly similar scales:—

Lines observed	Spectroscope[1] No. 1	No. 2	No. 3
Potassium	65·6	64·0	68·0
Lithium	80·8	80·0	81·5
Sodium	100·0	100·0	100·0
Thallium	118·4	119·0	117·5
Strontium	157·6	160·0	152·5
Rubidium	189·9	195·0	183·0
Potassium	207·4	214·0	198·0

In a *diffraction*-spectrum the position of the lines is dependent solely on their colour, and is precisely the same by whatever method the spectrum is obtained.

The following table shows the relative positions occupied by the Fraunhofer lines B D E F G in dispersion-spectra, produced by prisms of 60° of crown glass, of flint glass, and of carbon disulphide, with which are compared the positions of the same lines in a spectrum produced by diffraction. The interval between B and G is in each case divided into 1,000 equal parts.

	Dispersion			Diffraction
	Crown Glass	Flint Glass	Carbon Disulphide	
B	0	0	0	0
D	236	220	194	381
E	451	434	400	624
F	644	626	590	784
G	1000	1000	1000	1000

It will be noticed that the blue end of the spectrum is more compressed in the diffraction-spectrum than in any of the dispersion-spectra, and the red end is correspondingly lengthened out.

In order that the results obtained by different observers may be comparable, either the spectra must be obtained directly by the method of diffraction, or the results obtained with the prism must be *reduced to wave-lengths*.

The admirable determinations of the wave-lengths of the chief solar lines which we owe to Ångström, will of course form the basis of the reduction to wave-lengths, or when more convenient the measurements based upon them of the bright lines of metallic spectra made by Thalén. In the choice of reference-lines regard will of course be had to the accuracy

[1] *Spectres Lumineux*, p. 4.

of the measurements, since the wave-lengths of all lines are not known with equal accuracy.

If the wave-lengths are to be determined accurately to five figures, it is desirable to use as reference lines those only which are found in Ångström's map, or in the B. A. map of oscillation-frequencies.

The wave-length of the line to be measured may be calculated from those of two known lines between which it falls by means of the formula:

$$\lambda_2^2 = \frac{n_3 - n_1}{\frac{n_2 - n_1}{\lambda_3^2} + \frac{n_3 - n_2}{\lambda_1^2}}$$

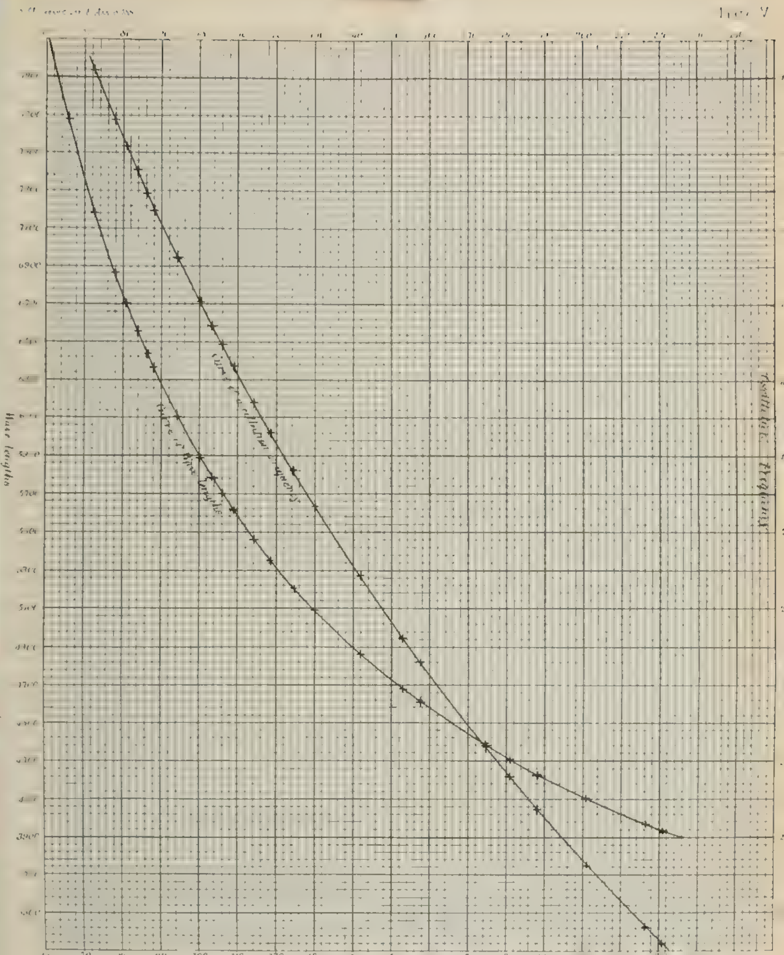
where n_3 and n_1 are the readings on the scale of the spectroscope of the two known lines, λ_3 and λ_1 their wave-lengths, n_2 the reading of the line to be measured, and λ_2 its wave-length. It is desirable that the two known lines should be as close to the one to be measured as possible; when sufficiently close the above formula gives the same result as a simple proportion.

To give an idea of the accuracy of the results obtainable by use of the above formula we may suppose the problem to be to determine the wave-length of a certain strontium line from the wave-lengths of the following three pairs of lines between which it lies. The actual wave-length of the line in question, as given by Thalen (corrected), is 5533·64. The scale-readings are Kirchhoff's:—

Case 1.	$n_1 = 1274{\cdot}2$	$\lambda_1 = 5534{\cdot}21$	Here the formula and simple proportion both give $\lambda_2 = 5533{\cdot}60$.
	$n_2 = 1274{\cdot}7$		
	$n_3 = 1276{\cdot}2$	$\lambda_3 = 5531{\cdot}77$	
Case 2.	$n_1 = 1268{\cdot}0$	$\lambda_1 = 5542{\cdot}10$	The formula gives 5534·00, and a simple proportion gives 5534·01.
	$n_2 = 1274{\cdot}7$		
	$n_3 = 1281{\cdot}3$	$\lambda_3 = 5526{\cdot}05$	
Case 3.	$n_1 = 1242{\cdot}6$	$\lambda_1 = 5571{\cdot}82$	Here the formula gives 5533·82, and a simple proportion 5534·22.
	$n_2 = 1274{\cdot}7$		
	$n_3 = 1306{\cdot}7$	$\lambda_3 = 5496{\cdot}74$	

But a far more convenient plan, and one quite equal to the above in accuracy, is that of *graphical interpolation*, which has also the great advantage of enabling us to detect at once any reading inconsistent with the rest, so giving the best mean result of all the observations.

A scale of wave-lengths is marked off along one edge of a sheet of paper ruled into squares (inches and tenths or millimetres), and the edge at right angles to this has a scale marked on it corresponding to the scale of the instrument. The positions of as many lines as can be ascertained with precision are mapped on the paper, and a smooth curve is then drawn through all these points, or through as many as possible, and having the rest as near the curves as possible, and as many above as below. In this way one observation is corrected by another, and the curve is more likely to give correct results than an irregular line made up of many straight portions which would pass through all of the points. The position of a line to be measured being found on the curve, will have opposite to it the wave-length sought. Various devices may be employed to facilitate the drawing of the curve. A smooth thin steel rule, which can be bent by the hands into the curve required, will be found useful. It requires, however, the co-operation of two persons—one to hold the rule



Illustrating the Report of the Committee on Spectrum Analysis.

down on the paper (stretched on a drawing-board), and the other to rule the curve with a finely pointed hard pencil. The author of this report employs a little drawing instrument consisting of a steel bar, mounted on a brass base which rests on the paper. By means of clamping-screws the steel bar can be held bent in the required curve, whether of equal curvature throughout its length, or more curved in one part than another.

A somewhat different method of procedure is described in a paper by Mr. Wm. Dodgson in the sixth volume of the third series of the 'Memoirs of the Literary and Philosophical Society of Manchester.'

The best paper for the purpose is a paper ruled into millimetres and centimetres made in rolls 69 centimetres broad, which may be obtained through Messrs. Williams and Norgate, 14, Henrietta Street, Covent Garden, or a somewhat similar paper to be obtained from Messrs. Lechertier, Barbe and Co., of 60, Regent Street. These papers are more uniform and free from shrinkage than any others. Another paper also ruled in millimetres, in sheets 1 metre by 7 decimetres, is to be obtained from C. Dupressoir, Rue St. Honoré, 175, Paris. A paper, ruled in inches and tenths, 24 inches by 15 inches, is to be obtained from Waterlow and Sons, 60 and 61, London Wall, but it is hardly uniform enough for the purpose. Some trouble expended in drawing a good curve will be very well repaid. The line obtained in this way will generally be very much curved, but the less curved it is the more easily is it drawn and the more exactly can it be employed. A less curved line is obtained by using the reciprocals of the wave-lengths instead of the wave-lengths themselves.[1] The adoption of this scale of inverse wave-lengths or of oscillation-frequencies is strongly recommended by a Committee of the British Association, under whose superintendence a catalogue[2] of oscillation-frequencies and a corresponding map of the Fraunhofer lines have been prepared. It is hoped that this catalogue will be extended to the bright lines of metals not present in the sun's atmosphere.

The map of oscillation-frequencies is intermediate between a diffraction-spectrum and a dispersion-spectrum, the red end being less extended when compared with the blue end than in Ångström's map, and more extended than in Kirchhoff's. A map drawn to wave-lengths is too much distorted to be advantageously employed with a dispersion-spectroscope, and, on the other hand, a spectrum mapped with a dispersion-spectroscope does not sufficiently resemble the same spectrum seen with a diffraction-spectroscope; but a map of oscillation-frequencies, being intermediate between the two, is not so different from either but that it is suitable for use both with diffraction-spectroscopes and with dispersion-spectroscopes. Further rays which are harmonically related are represented in the map of oscillation-frequencies by equidistant lines and in the catalogue by an arithmetic series whose common difference is equal to its first term. The map accompanying this report shows the scale of a one-prism spectroscope reduced both to wave-lengths and to oscillation-frequencies. It will be seen that the second line is much less curved than the first.

[1] If the *squares* of the reciprocals be employed the interpolation curve will be very nearly (but only *nearly*) a straight line.

[2] *British Association Report*, 1878, Dublin Meeting.

PAPERS CONNECTED WITH SPECTRUM ANALYSIS PUBLISHED SINCE 1870.

List of Periodicals to which References are given.

Periodical	Abbreviations.
'Philosophical Transactions of the Royal Society of London'	'Phil. Trans.'
'Proceedings of the Royal Society of London'	'Proc. Roy. Soc.'
'Philosophical Magazine'	'Phil. Mag.'
'Journal of the Chemical Society of London'	'J. Chem. Soc.'
'Monthly Notices of the Royal Astronomical Society of London'	'Monthly Not. Astr. Soc.'
'Proceedings of the Philosophical Society of Cambridge'	'Proc. Phil. Soc. Camb.'
'Proceedings of the Manchester Philosophical Society'	'Proc. Man. Phil. Soc.'
'Journal of the Iron and Steel Institute'	'J. Iron and Steel Inst.'
'Nature'	'Nature.'
'American Journal of Science and Art' (Silliman's)	'Am. J.'
'Proceedings of the American Academy'	'Proc. Am. Acad.'
'Journal of the Franklin Institute'	'J. Franklin Inst.'
'Comptes Rendus de l'Académie des Sciences'	'C. R.'
'Annales de Chimie et de Physique'	'Ann. Chim. et Phys.'
'Bulletin de la Société Chimique de Paris'	'Bull. Soc. Chim.'
'Journal de Physique'	'J. de Phys.'
'Bulletins de l'Académie Royale de Belgique'	'Bull. de l'Acad. de Belgique.'
'Archives Néerlandaises'	'Archives Néerlandaises.'
'Archives des Sciences Physiques et Naturelles de Genève'	'Arch. de Genève.'
'Annalen der Physik und Chemie	'Ann. Phys. u. Chem.'
'Beiblätter zu der Annalen der Physik und Chemie'	'Beiblätter.'
'Annalen der Chemie und Pharmacie'	'Ann. Chem. u. Pharm.'
'Berichte der deutschen chemischen Gesellschaft'	'Ber.'
'Journal für praktische Chemie'	'J. pr. Chem.'
'Dingler's polytechnischer Journal'	'Dingl. J.'
'Monatsberichte der Königlich preussischen Akademie der Wissenschaften zu Berlin'	'Monatsb. Berl. Akad.'
'Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften zu Wien'	'Sitzungsb. Wien. Akad.'
'Berichte über die Verhandlungen der Königlich sächsischen Gesellschaft der Wissenschaften zu Leipzig'	'Ber. K. sächs. Ges. d. Wiss.'
'Sitzungsberichte der Königlich baierischen Akademie zu München'	'Sitzungsb. Akad. München.'
'Sitzungsberichte der phys.-medicinischen Societät zu Erlangen'	'Sitzungsb. phys.-med. Soc. Erlangen.'
'Vierteljahrsschrift der Naturforscher-Gesellschaft in Zürich'	'Vierteljahrsschr. Naturf. Ges. Zürich.'
'Wiener Anzeiger'	'Wien. Anz.'
'Zeitschrift für Chemie'	'Zeitschr. f. Chem.'
'Zeitschrift für analytische Chemie'	'Zeitschr. f. anal. Chem.'
'Zeitschrift für Krystallographie und Mineralogie'	'Zeitschr. f. Kryst. u. Min.'
'Jahrbuch für Mineralogie'	'Jahrb. f. Mineral.'
'Pflüger's Archiv für Physiologie'	'Pflüger's Archiv f. Physiol.'
'Zeitschrift für Biologie'	'Zeitschr. f. Biol.'
'Zeitschrift für physiologische Chemie'	'Zeitschr. f. physiol. Chem.'
'Chemisches Centralblatt'	'Chem. Centr.'
'Astronomische Nachrichten'	'Astron. Nachr.'
'Memorie della Società degli Spettroscopisti Italiani'	'Mem. Spettr. Ital.'
'Gazzetta Chimica Italiana'	'Gazz. Chim. Ital.'

INSTRUMENTAL.

1870.

C. A. Young	Spectroscopic Notes. (Oct. 3, 1870.)	'J. Franklin Inst.' lx. 331–340; 'Nature,' iii. 110–113.
S. Merz	On a Small Universal Stellar Spectroscope. (Nov. 1870.)	'Phil. Mag.' [4] xli. 129–132.
H. Grubb	Automatic Spectroscope for Dr. Huggins's Sun Observations.	'Monthly Not. Astr. Soc.' xxxi. 36–38.
R. A. Proctor	On a Contrivance for extending the principle of Mr. Browning's Automatic Spectroscope to a second battery of Prisms. (Read Dec. 9.)	'Monthly Not. Astr. Soc.' xxxi. 47–48.

1871.

W. Huggins	On a Registering Spectroscope. (Recd. Jan. 14, 1871. Read Feb. 16, 1871.)	'Proc. Roy. Soc.' xix. 317–318; 'Phil. Mag.' [4] xli. 544–546; 'Ann. Chim. et Phys.' [4] xxvi. 275–276; 'Chem. News,' xxiii. 98.
J. Müller	Eine Interferenz-Scala für das Spectroskop.	'Dingl. J.' cxcix. 133–145.
"	Combination der Interferenzscala mit der photographischen Spectralscala.	'Dingl. J.' cxcix. 268–271.
F. Kohlrausch	Ueber ein einfaches Mittel, die Ablenkung oder Zerstreuung eines Lichtstrahles zu vergrössern. (April 1871.)	'Ann. Phys. u. Chem.' cxliii. 147–149.
A. Secchi	Eine neue Methode, die Sonne spectroskopisch zu beobachten.	'Ann. Phys. u. Chem.' cxliii. 154–155; 'Ann. Chim. et Phys.' [4] xxvi. 276–277 (Abs.)
"	New Spectroscopic Combination. (April 19.)	'Am. J.' [3] i. 463–464; 'Monthly Not. Astr. Soc.' xxxi. 202–203.
H. Fleck	Ueber die Anwendung eines Reflectors bei Spectraluntersuchungen.	'J. pr. Chem.' [2] iii. 352–355; 'J. Chem. Soc.' [2] ix. 857 (Abs.)
J. Browning	Note on the Use of Compound Prisms. (Read May 12.)	'Monthly Not. Astr. Soc.' xxxi. 203–205.
R. A. Proctor	A Contrivance for a Double Automatic Spectroscope, with Compound Prisms on Mr. Grubb's plan. (Read May 12.)	'Monthly Not. Astr. Soc.' xxxi. 205–208.
A. Crova	Sur les phénomènes d'interférence produits par les réseaux parallèles. (Read June 26.)	'C. R.' lxxii. 855–858.

INSTRUMENTAL, 1871–1873.

E. Lommel . .	Gefärbte Gelatinblättchen als Objecte für das Spectroskop. (July 26, 1871.)	'Sitzungsber. phys.-med. Soc. zu Erlangen,' 1871, 105–106; 'Ann. Phys. u. Chem.' cxliii. 656–657; 'J. Chem. Soc.' [2] x. 118 (Abs.); 'Ann. Chim. et Phys.' [4] xxvi. 279 (Abs.)
Alvergniat . .	Sur des tubes lumineux à électrodes extérieures. (Read Aug. 28.)	'C. R.' lxxiii. 561; 'J. Chem. Soc.' [2] ix. 1141 (Abs.)
H. C. Sorby . .	On the best Form of Compound Prism for the Spectrum Microscope.	'Nature,' iv. 511–512.
A. Secchi . . .	Note sur un nouveau moyen d'observer les éclipses et les passages de Vénus. (Read Oct. 23.)	'C. R.' lxxiii. 984–985.
L. Schönn . .	Ueber die Anwendung cylindrischer Linsen bei Spectralbeobachtungen. (Nov. 20.)	'Ann. Phys. u. Chem.' cxliv. 334–335.
C. A. Young . .	Spectroscopic Notes	'Nature,' v. 85–88.
	1872.	
M. Th. Edelmann .	Ueber eine neue Methode der objectiven Darstellung von Metallspectren.	'Chem. Centr.' 1872, 691; 'J. Chem. Soc.' [2] xi. 461 (Abs.)
J. Browning . .	On an Universal Automatic Spectroscope. (Read March 8.)	'Monthly Not. Astr. Soc.' xxxii. 213–214.
,, . .	On a Tele-Spectroscope for Solar Observations. (Read March 8.)	'Monthly Not. Astr. Soc.' xxxii. 214–215.
A. Crova . . .	Sur les phénomènes d'interférence produits par les réseaux parallèles. (Read April 1.)	'C. R.' lxxiv. 932–936.
Hon. J. W. Strutt .	Preliminary Note on the Reproduction of Diffraction-gratings by means of Photography. (Recd. May 23. Read June 20.)	'Proc. Roy. Soc.' xx. 414–417; 'Phil. Mag.' [4] xliv. 392–394; 'Am. J.' [3] v. 216–217 (Abs.); 'Ann. Phys. u. Chem.' clii. 175–176 (Abs.).
Timiraesef . .	Eine neue Methode für spectralanalytische Untersuchungen. (S. Petersburg, Mar. 27.)	'Ber.' v. 328–329 (Abs.); 'J. Chem. Soc.' [2] x. 1113 (Abs.)
	Italian Spectroscopy . . .	'Nature,' vi. 465–466.
H. R. Procter . .	On a Measuring Apparatus for Direct-vision Spectroscopes.	,, vi. 473.
,, . .	Measurement of Faint Spectra. (Oct. 22.)	,, vi. 534.
F. Zöllner . .	Ueber das spectroskopische Reversionsfernrohr. (Read July 1.)	'Ber. d. K. sächs. Ges. d. Wiss.' xxiv. 129–134; 'Phil. Mag.' [4] xliv. 417–421; 'Ann. Phys. u. Chem.' cxlvii. 617–623.
	1873.	
B. Stewart . .	The Janssen-Lockyer Application of the Spectroscope.	'Nature,' vii. 301–302.

INSTRUMENTAL, 1873, 1874.

W. Huggins . .	Professor Balfour Stewart on the Spectroscope.	'Nature,' vii. 320–321.
B. Stewart . .	The Janssen-Lockyer Method . .	" vii. 381–382.
H. R. Procter . .	Glass Reading-Scales for Direct-vision Spectroscopes.	'Chem. News,' xxvii. 149 150.
" . .	Direct-Vision Micrometer Scale for Pocket Spectroscopes.	" xxvii. 150.
J. Browning . .	On a large Automatic Spectroscope. (Read April 9.)	'Monthly Not. Astr. Soc.' xxxiii. 410–411.
" . .	On a Spectrometer. (Read April 9.)	'Monthly Not. Astr. Soc.' xxxiii. 411.
F. P. le Roux . .	Sur un illuminateur spectral. (Read April 21.)	'C. R.' lxxvi. 998–1000.
C. A. Young . .	Note on the use of a diffraction 'grating' as a substitute for the train of prisms in a Solar Spectroscope. (May 9.)	'Am. J.' [3] v. 472–473; 'Phil. Mag.' [4] xlvi. 87–88; 'Ann. Phys. u. Chem.' clii. 368 (Abs.)
M. Th. Edelmann .	Apparat zur Objectivdarstellung der Metallspectren. (May 1.)	'Ann. Phys. u. Chem.' cxlix. 119–122.
O. N. Rood . .	On a Convenient Eye-piece Micrometer for the Spectroscope. (June 4.)	'Am. J.' [3] vi. 44–45; 'Phil. Mag.' [4] xlvi. 176.
H. Emsmann . .	Ein Spectroskop *à vision directe* mit nur einem Prisma.	'Ann. Phys. u. Chem.' cl. 636–640.
H. Draper . .	On Diffraction Spectrum Photography.	'Am. J.' vi. 401–409; 'Phil. Mag.' [4] xlvi. 417–425; 'Nature,' ix. 224–226; 'Ann. Phys. u. Chem.' cli. 337–350.
C. V. Zenger . .	On a New Spectroscope. (Oct. 17.)	'Phil. Mag. [4] xlvi. 439–445.

1874.

J. L. Soret . .	Spektroscop mit fluorescirendem Ocular.	'Ann. Phys. u. Chem.' Jubelband, 407–411.
H. Vogel . .	Ueber die Schwankungen in der chemischen Wirkung des Sonnenspektrums und über einen Apparat zur Messung derselben. (Jan. 5. Read Jan. 12.)	'Ber.' vii. 88–92; 'J. Chem. Soc.' [2] xii. 424 (Abs.); 'Am. J.' [3] vii. 414–415.
Lord Rayleigh .	On the Manufacture and Theory of Diffraction-Gratings.	'Phil. Mag.' [4] xlvii. 81–93, 193–205.
A. Mousson . .	Bemerkungen über die Einrichtung eines Dispersiometers. (July 1872.)	'Vierteljahrsschr. Naturf. Ges. Zürich,' 1872, 213–225; 'Ann. Phys. u. Chem.' cli. 137–147.
J. M. Blake . .	Notes on Diffraction Gratings. (Mar. 1874.)	'Am. J.' [3] viii. 33–39.
T. Grubb . .	On the Improvement of the Spectroscope. (Recd. April 30. Read April 30.)	'Proc. Roy. Soc.' xxii. 308–309; 'Phil. Mag.' [4] xlviii. 532–534; 'Chem. News,' xxix. 222–223.

INSTRUMENTAL, 1874, 1875.

G. G. Stokes	Note on the preceding Paper	'Proc. Roy. Soc. xxii. 309–310'; 'Phil. Mag.' [4] xlviii. 534.
F. Kessler	Ueber das einfache euthyoptrische Spectroscop. (Mar. 3.)	'Ann. Phys. u. Chem.' cli. 507–510.
W. H. M. Christie	Note on the Curvature of Lines in the Dispersion Spectrum, and the Method of correcting it. (March 10.)	'Monthly Not. Astr. Soc.' xxxiv. 263–265.
J. L. Soret	Spectroscope à oculaire fluorescent.	'Arch. de Genève,' [2] xlix. 338–343; 'Ann. Phys. u. Chem.' clii. 167–171. 'Am. J.' [3] viii. 64–65.
F. Zöllner	Ueber ein einfaches Ocular-spectroskop für Sterne. (Read April 23.)	'Ber. d. K. sächs. Ges. d. Wiss.' xxvii. 24–25; 'Phil. Mag.' [4] xlviii. 156–157; 'Ann. Phys. u. Chem.' clii. 503–505.
W. Simms	Note on a Paper by Mr. Christie, 'On a Method of Correcting the Curvature of the Lines of the Dispersion Spectrum.' (May 4. Read June 12.)	'Monthly Not. Astr. Soc.' xxxiv. 363–364.
Prazmowski	Sur l'achromatisme chimique. (Read July 13.)	'C. R.' lxxix. 107–110; 'J. Chem. Soc.' [2] xii. 1125 (Abs.)
H. G. Madan	On an Improvement in the Construction of the Spectroscope. (July 18.)	'Phil. Mag.' [4] xlviii. 116.
J. G. Hofmann	Sur un nouveau modèle de prisme pour spectroscope à vision directe. (Read Aug. 31.)	'C. R.' lxxix. 581.
B. Delachanal and A. Mermet.	Tube spectro-électrique ou fulgurator, destiné à l'observation des spectres des solutions métalliques. (Read Oct. 5.)	'C. R.' lxxix. 800–802.
B. Delachanal and A. Mermet.	Tube spectro-électrique ou fulgurator, appareil destiné à l'observation de spectres des solutions métalliques.	'Ann. Chim. et Phys.' [5] iii. 485–489; 'Ann. Phys. u. Chem.' clv. 474–477.
F. Kingdon	On an Improvement of the Bunsen Burner for Spectrum Analysis.	'Chem. News,' xxx. 259.

1875.

J. C. Draper	Projection of the Fraunhofer Lines of Diffraction and Prismatic Spectra on a Screen. (Nov. 25, 1874.)	'Am. J.' [3] ix. 22–24; 'Phil. Mag.' [4] xlix. 142–144.
B. Delachanal and A. Mermet.	Schwefelkohlenstoff - Stickoxydgaslampe und ihre Anwendung auf Photographie.	'Dingl. J.' ccxiv. 483–485.
H. W. Vogel	Beschreibung eines höchst einfachen Apparats um das Spectrum zu photographiren. (Jan. 1875.)	'Ann. Phys. u. Chem.' cliv. 306–307.
H. C. Sorby	On a New and Improved Microscope Spectrum Apparatus, and on its Application to various branches of Research. (Read April 7.)	'Monthly Mic. J.' xiii. 198–208.

INSTRUMENTAL, 1875–1877.

W. M. Watts . .	On a New Form of Micrometer for use in Spectroscopic Analysis. (Read June 26.)	'Proc. Phys. Soc.' i. 160–164; 'Phil. Mag.' [4] l. 81–85; 'Ann. Phys. u. Chem.' clvi. 313–318.
B. Delachanal and A. Mermet.	Nouveau tube spectro-électrique (fulgurator modifié.) (Read Oct. 26.)	'C. R.' lxxxi. 726–728; 'Nature,' xiii. 74–75.
R. Bunsen . .	Spectralanalytische Untersuchungen.	'Ann. Phys. u. Chem.' clv. 230–252, 366–384; 'Phil. Mag.' [4] l. 417–430, 527–539; 'J. Chem. Soc.' 1876, i. 665–667 (Abs.)
H. C. Sorby . .	On a new Method of measuring the Position of the Bands in Spectra. (Read Nov. 3.)	'Monthly Mic. J.' xiv. 269–273.

1876.

T. H. Marvin . .	On the Production of Spectra by the Oxyhydrogen Flame. (Dec. 16, 1875.)	'Phil. Mag.' [5] i. 67–68; 'J. Chem. Soc.' 1876, ii. 156 (Abs.)
J. N. Lockyer . .	Some Recent Methods of Spectroscopy.	'Chem. News,' xxxiii. 29.
B. Delachanal and A. Mermet.	Nouveau tube spectro-électrique .	'Bull. Soc. Chim.' [2] xxv. 194–197; 'J. Chem. Soc.' 1876, ii. 35–36 (Abs.)
G. W. Royston-Pigott	On a new Refractometer for measuring the Mean Refractive Index of Plates of Glass and Lenses by the employment of Newton's Rings. (Recd. Mar. 19. Read Mar. 23.)	'Proc. Roy. Soc.' xxiv. 393–399.
F. Kessler . .	Vorlesungsversuch: Objective Darstellung des Sonnenspectrums. (April 1876. Read April 10.)	'Ber.' ix. 577–578; 'J. Chem. Soc.' 1876, ii. 266 (Abs.)
W. Baily . . .	A New Arrangement for the Micrometer of the Automatic Spectroscope.	'Phil. Mag.' [5] i. 314–315.
J. L. Soret . .	Spectroscope à oculaire fluorescent. Seconde note.	'Arch. de Genève,' [2] lvii. 319–333; 'Ann. Chim. et Phys.' [5] xi. 72–86; 'Am. J.' [3] xiv. 415–416 (Abs.); 'Beiblätter,' i. 190–192 (Abs.)
Stoney . . .	Nouveau Spectroscope . .	'Monit. Scient.' [3] vi. 657.

1877.

Van Monckhoven .	Sur les moyens propres à la reproduction photographique des spectres ultra-violets du gaz. (Read Feb. 3.)	'Bull. de l'Acad. de Belgique' [2] xliii. 187–192; 'Beiblätter,' i. 286–287 (Abs.)
W. H. M. Christie .	On the Magnifying-power of the Half-prism as a means of obtaining great Dispersion, and on the General Theory of the Half-prism Spectroscope. (Recd. Jan. 25. Read Mar. 1.)	'Proc. Roy. Soc.' xxvi. 8–40; 'Beiblätter,' i. 556–561 (Abs.)

INSTRUMENTAL, 1877, 1878.

A. Hilger . .	Neues geradsichtiges Taschenspectroskop.	'Beiblätter,' i. 124–125.
S. P. Langley . .	A proposed New Method in Solar Spectrum Analysis. (April 14.)	'Am. J.' [3] xiv. 140–146; 'Beiblätter,' i. 621 (Abs.)
" . .	Nouvelle méthode spectroscopique. (Read May 21.)	'C. R.' lxxxiv. 1145–1147; 'Beiblätter,' i. 471–472.
P. Glan . . .	Ueber ein neues Photometer. (May 10.)	'Ann. Phys. u. Chem.' N.F. i. 351–360.
A. Cazin . . .	Sur la photographie du spectre de l'étincelle électrique.	'Bull. Soc. Philom. de Paris,' 1877 [7] i. 6–7; 'Beiblätter,' i. 287–288 (Abs.)
H. W. Vogel . .	Spectroskopische Notizen. I. Ein Universalstativ für Benutzung des Taschenspectroskops. II. Ueber die Untersuchungen von Himbeersaft. (July 1877. Read July 23.)	'Ber.' x. 1428–1432; 'J. Chem. Soc.' 1877, ii. 915 (Abs.); 'Beiblätter,' ii. 31–33 (Abs.)
W. Baily . . .	A New Automatic Motion for the Spectroscope.	'Phil. Mag.' [5] iv. 100–104.
Lavaut de Lestrade	Nouveau moyen de recomposer la lumière du spectre solaire.	'Les Mondes,' xlii. 579–580; 'Beiblätter,' i. 290 (Abs.)
C. Günther . .	Ueber ein einfaches Verfahren, die Umkehrung der farbigen Linien der Flammenspectra, insbesondere der Natriumlinie, subjectiv darzustellen. (July 7.)	'Ann. Phys. u. Chem.' N.F. ii. 477–478.
G. Hüffner . .	Ueber quantitative Spectralanalyse und ein neues Spectrophotometer.	'J. pr. Chem.' 1877, xvi. 290–313.
J. Luvini . . .	Miroir tremblant pour la recomposition des couleurs du spectre.	'Les Mondes,' xliii. 427–429; 'Beiblätter,' i. 556 (Abs.)
Moigno . . .	Nouvelle méthode pour projeter les spectres.	'Les Mondes,' xliii. 554–555; 'Beiblätter,' i. 555–556.
Lavaut de Lestrade	Recomposition de la lumière spectrale.	'Les Mondes,' xliii. 828–830.
J. Luvini . .	Recomposition de la lumière spectrale.	'Les Mondes,' xliv. 97–99.
Lavaut de Lestrade	Miroir tournant pour la recomposition de la lumière spectrale.	'Les Mondes,' xliv. 416–417.

1878.

v. Zahn . . .	Ueber ein Spectrophotometer. (Read Jan. 8.)	'Ber. Naturf. Ges. Leipzig.' v. 1–4.
J. E. Reynolds .	On a New Form of Measuring Apparatus for a Laboratory Spectroscope. (Read Feb. 19, 1877.)	'Scientif. Proc. Roy. Dub. Soc.' New Series, i. 5–9; 'Phil. Mag.' [5] v. 106–110; 'Chem. News,' xxxvii. 115–116.
L. Thollon . .	Nouveau spectroscope à vision directe. (Read Feb. 4.)	'C. R.' lxxxvi. 329–331; 'Beiblätter,' ii. 253–254 (Abs.)

INSTRUMENTAL, 1878, 1879.

J. N. Lockyer . .	On the Use of the Reflecting Grating in Eclipse Photography. (Recd. Feb. 8. Read Feb. 14.)	'Proc. Roy. Soc.' xxvii. 107–108.
W. Erck . . .	Improvements in a Solar Spectroscope made by Mr. Grubb for Professor Young. (Read March 8.)	'Monthly Not. Astr. Soc.' xxxviii. 331–332.
H. W. Vogel . .	Ueber einen Universalapparat zu spektroskopischen Beobachtungen. (May 22.)	'Chem. Centr.' 1878, 335; 'J. Chem. Soc.' xxxiv. 829 (Abs.)
J. N. Lockyer . .	An Eclipse Spectroscope . . .	'Nature,' xviii. 224–225.
Thollon . . .	Nouveau spectroscope . . .	'J. de Phys.' vii. 141–148.
A. S. Herschel . .	Measuring Scales for Pocket Spectroscopes.	'Nature,' xviii. 300–301; 'Beiblätter,' ii. 560–561 (Abs.)
V. v. Lang . .	Verbindung des Spektralapparates mit dem Axenwinkelapparate.	'Zeitschr. f. Kryst. u. Mineral.' ii. 492–494; 'Beiblätter,' ii. 657 (Abs.)
	1879.	
A. Thollon . .	Nouveau prisme composé, pour spectroscope à vision directe, de très grand pouvoir dispersif. (Read Jan. 13.)	'C. R.' lxxxviii. 80–82; 'Beiblätter,' iii. 355–356 (Abs.)
L. Laurent . .	Sur le spectroscope de M. Thollon. (Read Jan. 13.)	'C. R.' lxxxviii. 82–84; 'Beiblätter,' iii. 355–356 (Abs.); 'Les Mondes,' xlviii. 199–200 (Abs.)
G. Hüfner . .	Ueber eine nützliche Vereinfachung des Spectralapparates.	'Carl. Repert.' xv. 116–118.
F. v. Lepel . .	Ein neues Universalstativ für die Benutzung des Taschenspectroskopes. (Recd. Feb. 13.)	'Ber.' xii. 263–266; 'Beiblätter,' iii. 501 (Abs.)
Piazzi Smyth . .	Illumination in Spectroscopy. (Abstract of paper upon 'End-on in place of Transverse Illumination in Private Spectroscopy.')	'Nature,' xix. 400.
,, . .	End-on Gas Vacuum Tubes in Spectroscopy. (Feb. 28.)	'Nature,' xix. 458; 'Beiblätter,' iii. 604–605 (Abs.)
A. Riccò . . .	Combinazioni spettroscopiche a visione diretta. (March 1879.)	'Mem. spettr. ital.' viii. 21–34.
Thollon . . .	Spectroscopes à vision directe et à grande dispersion.	'J. de Phys.' viii. 73–77.
A. Schuster . .	An Easy Method for Adjusting the Collimator of a Spectroscope.	'Proc. Phys. Soc.' iii. 14–17; 'Phil. Mag.' [5] vii. 95–98; 'Beiblätter,' iii. 354 (Abs.)
A. Crova . . .	Note sur les spectrophotomètres .	'J. de Phys.' viii. 85–92; 'Beiblätter,' iii. 356 (Abs.)
G. D. Liveing and J. Dewar.	Note on a Direct-vision Spectroscope after Thollon's Plan, adapted to Laboratory Use and capable of giving exact Measurements. (Recd. April 3. Read April 3.)	'Proc. Roy. Soc.' xxviii. 482–483; 'Beiblätter,' iii. 709 (Abs.)

INSTRUMENTAL, 1879, 1880.

Piazzi Smyth . .	End-on Tubes brought to Bear upon the Carbon and Carbo-hydrogen Question. (May 9.)	'Nature,' xx. 75–76.
W. de W. Abney .	On the Photographic Method of Registering Absorption-Spectra, and its application to Solar Physics.	'Proc. Phys. Soc.' iii. 43–46; 'Phil. Mag.' [5] vii. 313–316; 'Beiblätter,' iii. 621.
J. W. Draper . .	On a new form of Spectrometer, and on the distribution of the intensity of Light in the Spectrum. (May 5.)	'Am. J.' xviii. 30–34; 'Phil. Mag.' [5] viii. 75–80; 'Beiblätter,' iii. 870–871 (Abs.)
A. Cornu . . .	Spectroscope pour la partie ultra-violette du spectre.	'Les Mondes,' xlix. 16–17; 'Beiblätter,' iii. 501 (Abs.)
" . . .	Spectroscope destiné à l'observation des radiations ultra-violettes.	'J. de Phys.' viii. 185–193; 'Beiblätter,' iv. 34 (Abs.)
A. Riccò . . .	Arcobaleno in mare e modficazione allo spettroscopio descritto nel vol. V. (Sept. 1879.)	'Mem. Spettr. ital.' viii. 87.
H. Draper . .	On Photographing the Spectra of Stars and Planets.	'Am. J.' [3] xviii. 419–425; 'Nature,' xxi. 83–85.
L. Thollon . .	Sur un nouveau spectroscope stellaire. (Read Nov. 3.)	'C. R.' lxxxix. 749–752; 'Beiblätter,' iv. 360–361 (Abs.)
J. N. Lockyer . .	On a New Method of Spectrum Observation. (Recd. Dec. 10. Read Dec. 18.)	'Proc. Roy. Soc.' xxx. 22–31; 'Chem. News,' xli. 84–87; 'Am. J.' [3] xix. 303–311; 'Beiblätter,' iv. 361–362 (Abs.); 'Ber.' xiii. 938–939 (Abs.)
W. von Zahn . .	Spectralröhren mit longitudinaler Durchsicht.	'Ann. Phys. u. Chem.' N.F. viii. 675.
S. Lamansky . .	Un spectroscope pour étudier les phénomènes de fluorescence.	'J. de Phys.' viii. 411–413; 'Beiblätter,' iv. 375 (Abs.)

1880.

W. A. Rogers . .	On the first Results from a new Diffraction Ruling Engine. (Oct. 28, 1879.)	'Am. J.' [3] xix. 54–59.
P. Glan . . .	Ueber ein Spectroteleskop. (Jan. 4.)	'Ann. Phys. u. Chem.' N.F. ix. 492–502; 'Astr. Nachr.' xcvii. 65–68; 'Phil. Mag.' [5] xi. 110–113; 'Beiblätter,' v. 43–44 (Abs.)
W. H. Stone . .	On a Quartz and Iceland Spar Spectroscope corrected for chromatic aberration.	'Chem. News,' xli. 91.
F. Miller . . .	Das Lang'sche Spectrometer . .	'Carl. Repert.' xvi. 250–251.
P. G. Tait . .	A Rotatory Polarisation Spectroscope of Great Dispersion. (Aug. 12.)	'Nature,' xxii. 360–361; 'Beiblätter,' iv. 725–726 (Abs.)

STRUMENTAL, 1880, 1881—EMISSION SPECTRA, 1870, 1871.

P. Glan	Ueber Apparate zur Untersuchung der Farbenempfindungen. (Nov. 22.)	'Pflüger's Archiv f. Physiol.' xxiv. 307–308; 'Beiblätter,' v. 445 (Abs.)

1881.

A. Crova	Étude sur les spectrophotomètres. (Read Jan. 3.)	'C. R.' xcii. 36–37; 'Phil. Mag.' [5] xi. 155–156.
H. C. Vogel	Vermischte Mittheilungen, betreffend Spectral-apparate.	'Zeitschr.f.Instrumentenkunde,' i. 19–22, 47–51; 'Beiblätter,' v. 279–280 (Abs.)
O. Lohse	Ueber einen rotirenden Spectralapparat.	'Zeitschr. f. Instrumentenkunde,' i. 22–25; 'Beiblätter,' v. 278 (Abs.)
E. J. Stone	On a Method of Destroying the Effects of slight Errors of Adjustment in Experiments of Changes of Refrangibility due to Relative Motions in the Line of Sight. (Recd. Jan. 17. Read Feb. 3.)	'Proc. Roy. Soc.' xxxi. 381.
G. G. Stokes	On a Simple Mode of Eliminating Errors of Adjustment in Delicate Observations of Compared Spectra. (Recd. Feb. 12. Read Feb. 24.)	'Proc. Roy. Soc.' xxxi. 470–473; 'Beiblätter,' v. 360–361 (Abs.)
Lord Rayleigh	On Copying Diffraction-gratings, and on some Phenomena connected therewith. (Jan. 29.)	'Phil. Mag.' [5] xi. 196–205; 'Beiblätter,' v. 594–596 (Abs.)
W. N. Hartley	Description of the Instruments and Processes employed in Photographing Ultra-violet Spectra. (Read April 11.)	'Proc. Dub. Soc.' iii.
C. V. Zenger	Sur l'emploi de prismes à liquide dans le spectroscope à vision directe. (Read June 27.)	'C. R.' xcii. 1503–1504.
W. Dietrich	Die Anwendung des Vierordt'schen Doppelspaltes in der Spectral-Analyse.	'Beiblätter,' v. 438–441 (Abs.)

EMISSION SPECTRA.

1870.

F. Zöllner	Ueber den Einfluss der Dichtigkeit und Temperatur auf die Spectra glühender Gase. (Read Oct. 31.)	'Ber. K sächs. Ges. d. Wiss.' xxii. 233–253; 'Ann. Phys. u. Chem.' cxlii. 88–111; 'Phil. Mag.' [4] xli. 190–205.

1871.

W. M. Watts	On the Spectra of Carbon.	'Phil. Mag.' [4] xli. 12–15; 'J. Chem. Soc.' [2] ix. 97 (Abs.)

EMISSION SPECTRA, 1871, 1872.

A. Wüllner . .	Des transformations que subissent les spectres des gaz incandescents avec la pression et la température.	'Arch. de Genève,' [2] xl. 305–310.
A. J. Ångström .	Sur les spectres des gaz simples. (Read Aug. 7.)	'C. R.' lxxiii. 369–375; 'J. Chem. Soc.' [2] ix. 991–992 (Abs.); 'Phil. Mag.' [4] xlii. 395–399; 'Ann. Phys. u. Chem.' cxliv. 300–307; 'Ann. Chim. et Phys.' [4] xxvi. 255–258 (Abs.)
G. Salet . . .	Sur les spectres du soufre. (Read Aug. 28.)	'C. R.' lxxiii. 559–561; 'Phil. Mag.' [4] xlii. 318–319; 'J. Chem. Soc.' [2] ix. 1145–1146 (Abs.)
H. Vogel . . .	Ueber die Spectra der Blitze. (Sept. 11.)	'Ann. Phys. u. Chem.' cxliii. 653–654; 'J. Chem. Soc.' [2] x. 118 (Abs.); 'Ann. Chim. et Phys.' [4] xxvi. 274 (Abs.)
L. Troost and P. Hautefeuille.	Sur les spectres du carbone, du bore, du silicium, du titane et du zirconium. (Read Sept. 4.)	'C. R.' lxxiii. 620–622; 'J. Chem. Soc.' [2] ix. 1147 (Abs.)
A. Ditte . . .	Sur les spectres du soufre, du sélénium et du tellure. (Read Sept. 4.)	'C. R.' lxxiii. 622–624; 'J. Chem. Soc.' [2] ix. 1146–1147 (Abs.)
Lecoq de Boisbaudran	Sur la constitution des spectres lumineux.	'C. R.' lxxiii. 658–660.
A. Ditte . . .	Sur les spectres des corps appartenant aux familles de l'azote et du chlore. (Read Sept. 18.)	'C. R.' lxxiii. 738–742; 'J. Chem. Soc.' [2] ix. 1144–1145 (Abs.)
G. Salet . . .	Sur les spectres du sélénium et du tellure. (Read Sept. 18.)	'C. R.' lxxiii. 742–745; 'J. Chem. Soc.' [2] ix. 1145–1146 (Abs.)
A. Wüllner . .	Ueber die Spectra einiger Gase in Geissler'schen Röhren. (Nov. 15.)	'Ann. Phys. u. Chem.' cxliv. 481–525; 'Ann. Chim. et Phys.' [4] xxvi. 258–263 (Abs.)
G. M. Seabroke .	On the Spectrum of Hydrogen at Low Pressure. (Dec. 8, 1871.)	'Monthly Not. Astr. Soc.' xxxii. 63–64; 'Phil. Mag.' [4] xliii. 155–157; 'Chem. News,' xxv. 111; 'Ann. Chim. et Phys.' [4] xxvi. 264–265 (Abs.)

1872.

Salet . . .	Das Spectrum des Kohlenstoffs ('Chem. Soc. Paris,' Mar. 1.)	'Ber.' v. 222 (Abs.)
Lecoq de Boisbaudran	Sur le spectre de la vapeur d'eau. (Read April 15.)	'C. R.' lxxiv. 1050.
G. Salet . . .	Sur la lumière émise par la vapeur d'iode. (Read May 6.)	'C. R.' lxxiv. 1249; 'J. Chem. Soc.' [2] x. 596 (Abs.); 'Am. J.' iv. 59; 'Ann. Phys. u. Chem.' cxlvii. 319–320.

EMISSION SPECTRA, 1872, 1873.

L. Cailletet . .	De l'influence de la pression sur les raies du spectre. (Read May 13.)	'C. R.' lxxiv. 1282-1285; 'Phil. Mag.' [4] xliv. 76–77; 'J. Chem. Soc.' [2] x. 664–665 (Abs.) 'Ber.' v. 482 (Abs.)
J. W. Draper . .	Researches in Actino-Chemistry. Memoir First. On the Distribution of Heat in the Spectrum.	'Am. J.' iv. 161–175; 'Phil. Mag.' [4] xliv. 104–117; 'J. Chem. Soc.' [2] x. 968–970 (Abs.)
A. Schuster . .	On the Spectrum of Nitrogen. (Recd. June 13. Read June 20.)	'Proc. Roy. Soc.' xx. 484–487; 'Phil. Mag.' [4] xliv. 537–541; 'Ann. Phys. u. Chem.' cxlvii. 106–112; 'Am. J.' [3] v. 131–132 (Abs.); 'J. Chem. Soc.' [2] xi. 340 (Abs.)
G. Salet . . .	Sur le spectre primaire de l'iode. (Read July 8.)	'C. R.' lxxv. 76–77; 'J. Chem. Soc.' [2] x. 873 (Abs.); 'Phil. Mag.' [4] xliv. 156.
A. Wüllner . .	Ueber die Spectra der Gase in Geissler'schen Röhren. (July 14.)	'Ann. Phys. u. Chem.' cxlvii. 321–353.

1873.

G. Salet . . .	Sur les spectres des métalloïdes .	'Ann. Chim. et Phys.' [4] xxviii. 5–71; 'Chem. News,' xxvii. 178–179 (Abs.)
Marquis of Salisbury	On Spectral Lines of Low Temperature.	'Phil. Mag.' [4] xlv. 241–245; 'J. Chem. Soc.' [2] xi. 711 (Abs.); 'Am. J.' [3] vi. 141–142 (Abs.)
C. H. Stearn . .	Spectrum of Nitrogen . . .	'Nature,' vii. 463.
Lecoq de Boisbaudran	Sur le spectre d'émission de l'erbine. (Read April 28.)	'C. R.' lxxvi. 1080–1082; 'Ber.' vi. 623; 'J. Chem. Soc.' [2] xi. 829–830.
C. H. Stearn and G. H. Lee.	On the Effect of Pressure on the Character of the Spectra of Gases. (Recd. Mar. 19. Read May 11.)	'Proc. Roy. Soc.' xxi. 282–283; 'J. Chem. Soc.' [2] xi. 996 (Abs.); 'Ber.' vi. 973 (Abs.); 'Phil. Mag.' [4] xlvi. 406–407.
W. Mattieu Williams	Coincidence of the Spectrum Lines of Iron, Calcium, and Titanium.	'Nature,' viii. 46.
A. Wüllner . .	Ueber die Spectra der Gase in Geissler'schen Röhren. (Jan. 12.)	'Ann. Phys. u. Chem.' cxlix. 103–112; 'J. Chem. Soc.' [2] xii. 113 (Abs.)
Lecoq de Boisbaudran	Remarques sur quelques particularités observées dans des recherches d'analyse spectrale. (Read May 19.)	'C. R.' lxxvi. 1263–1265; 'J. Chem. Soc.' [2] xi. 1257–1258 (Abs.)
A. Schuster . .	Spectrum of Nitrogen. (May 30) .	'Nature,' viii. 161.

EMISSION SPECTRA, 1873–1875.

L. Palmieri . .	Recherches spectroscopiques sur les fumerolles de l'éruption du Vésuve en avril 1872, et état actuel de ce volcan. (May 24. Read June 9.)	'C. R.' lxxvi. 1427–1428.
A. Secchi . .	Sur les spectres du fer et de quelques autres métaux, dans l'arc voltaïque. (July 16. Read July 21.)	'C. R.' lxxvii. 173–177.
O. Lohse . . .	Ueber das Spectrum des Lichts explodirender Schiessbaumwolle. (Nov. 28.)	'Ann. Phys. u. Chem.' cl. 641–642; 'Phil. Mag.' [4] xlvii. 319–320; 'J. Chem. Soc.' [2] xiii. 119–120.

1874.

J. N. Lockyer . .	Sur les spectres des vapeurs aux températures élevées. (Read June 29.)	'C. R.' lxxviii. 1790–1793; 'J. Chem. Soc.' [2] xii. 1124 (Abs.)
O. Schenk . .	Ueber Veränderlichkeit der Spectra glühender Gase.	'Zeitschr. f. Anal. Chem.' 1873, xii. 386–390; 'J. Chem. Soc.' [2] xii. 1122–1123 (Abs.)
E. Goldstein . .	Ueber Beobachtungen am Gasspektris. (Read Aug. 13.)	'Monatsb. Berl. Akad.' 1874, 593–610; 'Ann. Phys. u. Chem.' cliv. 128–149; 'J. Chem. Soc.' [2] xiii. 527–528 (Abs.) 'Phil. Mag.' [4] xlix. 333–345.
W. M. Watts . .	On the Spectrum of Carbon . .	'Phil. Mag.' [4] xlviii. 369–370; 'J. Chem. Soc.' [2] xiii. 327 (Abs.)
J. Chautard . .	Action exercée par un électro-aimant sur les spectres des gaz raréfiés, traversés par des décharges électriques. (Nov. 15. Read Nov. 16.)	'C. R.' lxxix. 1123–1124.
G. Salet . . .	Sur la distribution des bandes dans les spectres primaires. (Read Nov. 30.)	'C. R.' lxxix. 1229–1230; 'Ber.' vii. 1788 (Abs.)
Wüllner . . .	Einige Bemerkungen zu Herrn Goldsteins Beobachtungen an Gasspectris. (Read Dec. 3.)	'Monatsb. Berl. Akad.' 1874, 755–761; 'Phil. Mag.' [4] xlix. 448–453.
W. M. Watts . .	Note on Carbon Spectra . . .	'Phil. Mag.' [4] xlviii. 456–457.

1875.

H. W. Vogel . .	Ueber das Spectrum der Sell'schen Schwefelkohlenstofflampe. (Read Jan. 25.)	'Ber.' viii. 96–98; 'J. Chem. Soc.' [2] xiii. 603–604 (Abs.)
W. Wüllner . .	Ueber die Spectra der Gase. ('Verhandl. d. naturwiss. Ges. zu Aachen.' Dec. 1874.)	'Ann. Phys. u. Chem.' cliv. 149–156; 'J. Chem. Soc.' [2] xiii. 527–528 (Abs.)
Piazzi Smyth . .	Carbon and Hydrocarbon in the Modern Spectroscope.	'Phil. Mag.' [4] xlix. 24–33.

EMISSION SPECTRA, 1875, 1876.

J. Chautard . .	Action des aimants sur les gaz raréfiés renfermés dans des tubes capillaires et illuminés par un courant induit. (Read May 3.)	'C. R.' lxxx. 1161–1164.
J. Chautard . .	Phénomènes magnéto-chimiques produits au sein des gaz raréfiés dans les tubes de Geissler, illuminés à l'aide de courants induits. (Read July 12.)	'C. R.' lxxxi. 75–77; 'J. Chem. Soc.' 1876, i. 29 (Abs.)
W. M. Watts . .	Carbon and Hydrocarbon in the Modern Spectroscope.	'Phil. Mag.' [4] xlix. 104–106.
J. Attfield . .	Note on the Spectrum of Carbon .	'Phil. Mag.' [4] xlix. 106–108.
R. Bunsen . .	Spectralanalytische Untersuchungen.	'Ann. Phys. u. Chem.' clv. 230–252, 366–384; 'Phil. Mag.' [4] l. 417–430, 527–539; 'J. Chem. Soc.' 1876, i. 665–667 (Abs.)
	1876.	
Lecoq de Boisbaudran	Sur le spectre du gallium. (Read Jan 10.)	'C. R.' lxxxii. 168; 'Phil. Mag.' [5] i. 176; 'Chem. News,' xxxiii. 35; 'J. Chem. Soc.' 1876, i. 882 (Abs.); 'Ber.' ix. 348 (Abs.)
G. Salet . . .	Sur le spectre de l'azote et sur celui des métaux alcalins dans les tubes de Geissler. (Read Jan. 17 and 24.)	'C. R.' lxxxii. 223–226, 274–275; 'Nature,' xiii. 314; 'Phil. Mag.' [5] i. 331–333; 'J. Chem. Soc.' 1876, i. 863–864 (Abs.); 'Ann. Phys. u. Chem.' clviii. 329–334.
J. Chautard . .	Actions magnétiques exercées sur les gaz raréfiés des tubes de Geissler. (Read Jan. 24.)	'C. R.' lxxxii. 272–274.
J. N. Lockyer . .	Sur de nouvelles raies du calcium. (Read Mar. 20.)	'C. R.' lxxxii. 660–662; 'Ann. Chim. et Phys.' [5] vii. 569–572; 'Chem. News,' xxxiii. 166–167; 'J. Chem. Soc.' 1876, ii. 35 (Abs.); 'Ber.' ix. 505 (Abs.); 'Ann. Phys. u. Chem.' clviii. 327–329.
C. Sainte-Claire Deville.	Remarque à propos de la dernière Communication de M. Lockyer sur de nouvelles raies du calcium. (Read Mar. 27.)	'C. R.' lxxxii. 709–710.
J. N. Lockyer . .	Preliminary Note on the Compound Nature of the Line Spectra of Elementary Bodies. (Recd. Jan. 20. Read Mar. 2.)	'Proc. Roy. Soc.' xxiv. 352–354; 'Phil. Mag.' [5] ii. 229–231.
Czechowicz . .	Der Einfluss welchen die Natur der elektrischen Stromquelle auf das Aussehen von Gasspectren ausübt. ('Versamm. Russisch. Naturforsch. und Aerzte in Warschau.' Sept. 1876.)	'Ber.' ix. 1598 (Abs.)

EMISSION SPECTRA, 1876, 1877.

A. W. Clayden and C. T. Heycock.	The Spectra of Indium . .	'Phil. Mag.' [5] ii. 387–389; 'Am J.' [3] xiii. 57 (Abs.); 'Beiblätter,' i. 90–92.

1877.

Gouy . . .	Recherches sur les spectres des métaux à la base des flammes. (Read Jan. 29.)	'C. R.' lxxxiv. 231–234; 'J. Chem. Soc.' 1877, ii. 105–106. (Abs.); 'Ber.' x. 490. (Abs.); 'Phil. Mag.' [5] iii. 238–240; 'Chem. News,' xxxv. 107–108; 'Beiblätter,' i. 238–239 (Abs.)
J. Moser . .	Die Spectren der chemischen Verbindungen.	'Ann. Phys. u. Chem.' clx. 177–199; 'J. Chem. Soc.' 1877, ii. 688–690 (Abs.); 'Nature,' xvi. 193–194 (Abs.); 'Phil. Mag.' [5] iv. 444–449 (Abs.)
Van Monckhoven .	Sur les moyens propres à la reproduction photographique des spectres ultra-violets des gaz. (Feb. 3.)	'Bull. de l'Acad. de Belgique' [2] xliii. 187–192; 'Beiblätter,' i. 286–287 (Abs.)
A. J. Ångström and T. R. Thalén.	Researches on the Spectra of the Metalloids. ('Acta Soc. Upsal.' [3] ix.)	'Nature,' xv. 401–402 (Abs.); 'Beiblätter,' i. 35–47.
A. Schuster . .	Spectra of Metalloids . . .	'Nature,' xv. 447–448; 'Beiblätter,' i. 289–290 (Abs.)
A. Cazin . . .	Sur la photographie du spectre de l'étincelle électrique.	'Bull. Soc. Philom. de Paris,' 1877 [7] i. 6–7; 'Beiblätter,' i. 287–288 (Abs.)
" . . .	Sur le spectre de l'étincelle électrique dans un gaz comprimé. (Read May 21.)	'C. R.' lxxxiv. 1151–1154; 'Phil. Mag.' [5] iv. 153–156; 'Beiblätter,' i. 620–621 (Abs.); 'J. Chem. Soc.' xxxiv. 357–358 (Abs.); 'Am. J.' [3] xv. 148–149 (Abs.)
Wüllner . . .	Sur le spectre de l'étincelle électrique dans les gaz soumis à une pression croissante. (Read July 30.)	'C. R.' lxxxv. 280–281; 'Ann. Chim. et Phys.' [5] xii. 143–144; 'Beiblätter,' i. 620–621 (Abs.)
Serge Kern . .	Sur le spectre du nouveau métal, le davyum. (Read Oct. 8.)	'C. R.' lxxxv. 667.
G. Ciamician . .	Ueber die Spectren der chemischen Elemente und ihrer Verbindungen. (Read July 19.)	'Sitzungsb. Wien. Akad.' lxxvi. II. 499–517; 'Wien. Anz.' xiv. 181–182 (Abs.); 'J. Chem. Soc.' xxxvi. 685–686 (Abs.); 'Beiblätter,' iii. 190-193 (Abs.)

Emission Spectra, 1878, 1879.

1878.

F. Schöttner . .	Notiz über das Flammenspectrum der Schiessbaumwolle.	'Carl. Repert.' xiv. 55–56; 'Beiblätter,' iii. 279 (Abs.)
H. W. Vogel . .	Ueber das Spectrum des Lichtes explodirender Schiessbaumwolle. (Mar. 1878.)	'Ann. Phys. u. Chem.' N.F. iii. 615–616.
G. Ciamician . .	Ueber den Einfluss des Druckes und der Temperatur auf die Spectren von Dämpfen und Gasen.	'Sitzungsb. Wien. Akad.' lxxvii. II. 839–841; 'J. Chem. Soc.' xxxvi. 685–686 (Abs.); 'Nature,' xxiii. 160; 'Beiblätter,' iii. 193–194 (Abs.)
A. Schuster . .	On the Spectra of Metalloids. Spectrum of Oxygen. (Recd. April 25. Read May 16.)	'Phil. Trans.' 1879, clxx. 37–54; 'Proc. Roy. Soc.' xxvii. 383–388 (Abs.); 'Beiblätter,' ii. 492–493 (Abs.), iii. 749–750 (Abs.); 'J. Chem. Soc.' xxxviii. 430 (Abs.)
G. Ciamician . .	Ueber den Einfluss der Dichte und der Temperatur auf die Spectren von Dämpfen und Gasen. (Read July 18.)	'Sitzungsb. Wien. Akad.' lxxviii. 867–890; 'Chem. Centr.' 1879, 507–509, 537–542, 555–557; 'Nature,' xx. 90 (Abs.); 'Beiblätter,' iii. 609–611 (Abs.)
E. Walker . .	Spectrum of the Electric (Jablochkoff) Light. (July 27.)	'Nature,' xviii. 384; 'Beiblätter,' iii. 505 (Abs.)
Sir W. R. Grove .	Note of an Experiment on the Spectrum of the Electric Discharge. (Recd. Dec. 19. Read Dec. 19.)	'Proc. Roy. Soc.' xxviii. 181–184; 'Beiblätter,' iii. 360 (Abs.)
G. Ciamician . .	Ueber den Einfluss der Dichte und der Temperatur auf die Spectren von Dämpfen und Gasen.	'Wien. Anz.' 1878, 158–160; 'Chem. Centr.' 1878, 689–690; 'J. Chem. Soc.' xxxvi. 101 (Abs.)
Paalzow . .	Ueber das Sauerstoffspektrum und über die electrischen Lichterscheinungen verdünnter Gase in Röhren mit Flüssigkeits-Electroden. (Read Oct. 31.)	'Monatsb. Berl. Akad.' 1878, 705–709; 'Phil. Mag.' [5] vii. 297–300; 'Ann. Phys. u. Chem.' N.F. vii. 130–135; 'J. Chem. Soc.' xxxvi. 861.

1879.

G. L. Ciamician .	Spectroskopische Untersuchungen .	'Sitzungsb. Wien. Akad.' lxxix. 8–10; 'J. Chem. Soc.' xxxviii. 361 (Abs.); 'Nature' xxii. 575; 'Chem. News,' xl. 285 (Abs.)
Lecoq de Boisbaudran.	Nouvelles raies spectrales observées dans les substances extraites de la samarskite. (Read Feb. 17.)	'C. R.' lxxxviii. 322–324.

EMISSION SPECTRA, 1879.

H. W. Vogel	Ueber die photographische Beobachtung des Sauerstoffspectrums. (Jan. 1879. Read Feb. 24.)	'Ber.' xii. 332–334; 'J. Chem. Soc.' xxxvi. 497 (Abs.); 'Beiblätter,' iv. 125–130.
Gouy	Du pouvoir émissif des flammes colorées. (Read Mar. 3.)	'C. R.' lxxxviii. 418–421; 'Beiblätter,' iii. 611–613 (Abs.)
H. W. Vogel	Ueber die photographische Aufnahme von Spectren der in Geisslerröhren eingeschlossenen Gase. (Read Feb. 3.)	'Monatsb. Berl. Akad.' 1879, 115–119; 'Beiblätter,' iv. 125–130 (Abs.)
J. N. Lockyer	Note on some Spectral Phenomena observed in the Arc produced by a Siemens' Machine. (Recd. Mar. 3. Read Mar. 20.)	'Proc. Roy. Soc.' xxviii. 425–428; 'Beiblätter,' iii. 606–608 (Abs.)
B. O. Peirce	Ueber die Emissionsspectra der Haloïdverbindungen des Quecksilbers. (Dec. 1878.)	'Ann. Phys. u. Chem.' N.F. vi. 597–599; 'J. Chem. Soc.' xxxviii. 81 (Abs.)
J. N. Lockyer	Note on the Spectrum of Sodium. (Recd. May 28. Read May 29.)	'Proc. Roy. Soc.' xxix. 140.
"	Sur les raies de la vapeur de Sodium. (Read June 2.)	'C. R.' lxxxviii. 1124.
A. Abt	Continuirliches Spectrum des electrischen Funkens (K. Ungar. Acad. d. Wiss. in Buda-Pest. Dec. 16, 1878.)	'Ann. Phys. u. Chem.' N.F. vii. 159–160; 'J. Chem. Soc.' xxxvi. 765 (Abs.); 'Am. J.' [3] xviii. 68–69.
J. N. Lockyer	On a New Method of Studying Metallic Vapours. (Recd. June 19. Read June 19.)	'Proc. Roy. Soc.' xxix. 266–272; 'Beiblätter,' iv. 36–37 (Abs.)
J. W. Draper	The Blowpipe Cone-spectrum, and the Distribution of the Intensity of Light in the Prismatic and Diffraction Spectra.	'Nature,' xx. 301.
Piazzi Smyth	Carbon and Carbo-hydrogen, Spectroscoped and Spectrometed in 1879.	'Phil. Mag.' [5] viii. 107–119; 'Beiblätter,' iv. 36 (Abs.).
A. Schuster	Ueber das Sauerstoffspectrum	'Ann. Phys. u. Chem.' N.F. vii. 670–673.
H. W. Vogel	Ueber die Spectra des Wasserstoffs, Quecksilbers und Stickstoffs. (Read July 10.)	'Monatsb. Berl. Akad.' 1879, 586–604; 'Beiblätter,' iv. 125–130; 'Am. J.' [3] xix. 406 (Abs.)
A. Wüllner	Ueber das Spectrum des Sauerstoffs. (July 22.)	'Ann. Phys. u. Chem.' N.F. viii. 253–266.
"	Ueber allmähliche Ueberführung des Bandenspectrums des Stickstoffs in ein Linienspectrum. (April 8.)	'Sitzungsb. Akad. München,' 1879, 171–207; 'Ann. Phys. u. Chem.' N.F. viii. 590–623.
G. D. Liveing and J. Dewar.	On the Spectra of Sodium and Potassium. (Recd. Nov. 20. Read Nov. 27.)	'Proc. Roy. Soc.' xxix. 398–402; 'Beiblätter,' iv. 368–369 (Abs.)

EMISSION SPECTRA, 1879, 1880.

J. N. Lockyer	Note on the Spectrum of Hydrogen. (Recd. Dec. 17. Read Dec. 18.)	'Proc. Roy. Soc.' xxx. 31–32; 'Beiblätter,' iv. 363 (Abs.)
A. Schuster and H. E. Roscoe.	Note on the Identity of the Spectra obtained from the different Allotropic Forms of Carbon. (Read Dec. 2.)	'Proc. Manch. Phil. Soc.' xix. 46–49; 'Beiblätter,' iv. 208–209 (Abs.)

1880.

G. D. Liveing and J. Dewar.	On the Spectra of Magnesium and Lithium. (Recd. Jan. 8. Read Jan. 15.)	'Proc. Roy. Soc.' xxx. 93–99; 'Beiblätter,' iv. 366 (Abs.)
F. Lippich	Untersuchungen über die Spectra gasförmiger Körper.	'Sitzungsb. Wien. Akad.' lxxxii. II. 15–33.
G. D. Liveing and J Dewar.	On the Spectra of the Compounds of Carbon with Hydrogen and Nitrogen. (Recd. Feb. 2. Read Feb. 5.)	'Proc. Roy. Soc.' xxx. 152–162; 'Beiblätter,' iv. 459–460 (Abs.), v. 118–122. (Abs.) 'Am. J.' [3] xxi. 74–75 (Abs.)
H. W. Vogel	Ueber die neue Wasserstofflinien und die Dissociation des Calciums. (Feb. 6.)	'Ber.' xiii. 274–276; 'J. Chem. Soc.' xxxviii. 597–598 (Abs.); 'Beiblätter,' iv. 274–275.
"	Ueber die neuen Wasserstofflinien, die Spectra der weissen Fixsterne und die Dissociation des Calciums. (Read Feb. 12.)	'Monatsb. Berl. Akad.' 1880, 192–198; Beiblätter,' iv. 786–787 (Abs.)
"	The New Hydrogen Lines by Photography, the Star Lines and the Dissociation of Calcium. ('Photographic News,' Feb. 20.)	'Nature,' xxi. 410.
J. L. Schönn	Ueber ultraviolette Strahlen	'Ann. Phys. u. Chem.' N.F. ix. 483–492, x. 143–148.
C. Fiévez	Recherches sur l'intensité relative des raies spectrales de l'hydrogène et de l'azote, en rapport avec la constitution des nébuleuses.	'Bull de l'Acad. de Belgique' [2] xlix. 107–113; 'Phil. Mag.' [5] ix. 309–312; 'Beiblätter,' iv. 461–462 (Abs.)
J. R. Capron	Relative Intensity of the Spectral Lines of Gases. (April 2.)	'Phil. Mag.' [5] ix. 329–330; 'J. Chem. Soc.' xxxviii. 685 (Abs.); 'Beiblätter,' iv. 613–614 (Abs.)
J. N. Lockyer	Note on the Spectrum of Carbon. (Recd. April 8. Read April 29.)	'Proc. Roy. Soc.' xxx. 335–343; 'Beiblätter,' v. 118–122 (Abs.)
"	On Multiple Spectra	'Nature,' xxii. 4–7, 309–312, 562–565; 'Beiblätter,' v. 118–122 (Abs.)
"	Further Note on the Spectrum of Carbon. (Recd. May 11. Read May 27.)	'Proc. Roy. Soc.' xxx. 461–463; 'Beiblätter,' iv. 611 (Abs.) v. 118–122 (Abs.)

EMISSION SPECTRA, 1880, 1881.

G. D. Liveing and J. Dewar.	Note on the History of the Carbon Spectrum. (Recd. May 26. Read June 10.)	'Proc. Roy. Soc.' xxx. 490–494; 'Beiblätter,' v. 118–122 (Abs.)
,, . .	On the Spectra of the Compounds of Carbon with Hydrogen and Nitrogen. No. II. (Recd. May 27. Read June 10.)	'Proc. Roy. Soc.' xxx. 494–509; 'Nature,' xxii. 620–623; 'Beiblätter,' v. 118–122 (Abs.); 'Am. J.' [3] xxi. 74–75 (Abs.)
W. Huggins . .	On the Spectrum of the Flame of Hydrogen. (Recd. June 16. Read June 17.)	'Proc. Roy. Soc.' xxx. 576–580; 'Am. J.' [3] xx. 121–123; 'Beiblätter,' iv. 658 (Abs.)
,, . .	Sur le spectre lumineux de l'eau. (Read June 21.)	'C. R.' xc. 1455–1456; 'J. Chem. Soc.' xl. 1 (Abs.)
G. D. Liveing and J. Dewar.	On the Spectrum of Water. (Recd. June 17. Read June 17.)	'Proc. Roy. Soc.' xxx. 580–582; 'Beiblätter,' iv. 658–659 (Abs.)
Piazzi Smyth . .	Three Years' Experimenting in Mensurational Spectroscopy.	'Nature,' xxii. 193–195, 222–225.
G. L. Ciamician .	Spectroskopische Untersuchungen. (Read July 1.)	'Sitzungsb. Wien. Akad.' lxxxii. II. 425–457; 'Wien. Anz.' xvii. 138–141 (Abs.); 'Beiblätter,' v. 123 (Abs.); 'Chem. Centr.' 1880, 578–580 (Abs.); 'Phil. Mag.' [5] x. 212–213 (Abs.)
R. Thalén . .	Sur les raies brillantes spectrales du métal scandium. (Read July 5.)	'C. R.' xci. 45–48; 'Beiblätter,' iv. 787–789 (Abs.)
Piazzi Smyth . .	Gaseous Spectra in Vacuum Tubes. (Read July 19.)	'Proc. Roy. Soc. Edin.' x. 711–712 (Abs.)
A. S. Herschel. .	Carbon and Carbon Compounds .	'Nature,' xxii. 320; 'Beiblätter,' v. 118–122 (Abs.)
W. M. Watts . .	On the Spectrum of Carbon . .	'Nature,' xxiii. 197–198; 'Beiblätter,' v. 118–122 (Abs.)
	1881.	
G. D. Liveing . .	On the Spectrum of Carbon. (Jan. 4)	'Nature,' xxiii. 265–266; 'Beiblätter,' v. 118–122.
W. M. Watts . .	On the Spectrum of Carbon . .	'Nature,' xxiii. 266.
R.	On the Spectrum of Carbon . .	,, xxiii. 313–314.
G. D. Liveing . .	On the Spectrum of Carbon. (Jan 22.)	,, xxiii. 338.
W. M. Watts . .	On the Spectrum of Carbon. (Feb. 11.)	,, xxiii. 361.
C. Fiévez . .	Sur l'élargissement des raies de l'hydrogène. (Read Mar 7.)	'C. R.' xcii. 521–522; 'Beiblätter,' v. 281 (Abs.); 'J. Chem. Soc.' xl. 955 (Abs.)
A. Paalzow and H. W. Vogel.	Ueber das Sauerstoffspectrum. (Mar. 23.)	'Ann. Phys. u. Chem.' N.F. xiii. 336–338.

EMISSION SPECTRA, 1881—ABSORPTION SPECTRA, 1870, 1871.

G. D. Liveing and J. Dewar.	Investigations on the Spectrum of Magnesium. (Recd. April 28. Read May 12.)	'Proc. Roy. Soc.' xxxii. 189–203.
W. Crookes . .	On Discontinuous Phosphorescent Spectra in High Vacua. (Recd. March 31. Read May 19.)	'Proc. Roy. Soc.' xxxii. 206–213; 'Chem. News,' xliii. 237–239.
G. D. Liveing and J. Dewar.	On the Identity of the Spectral Lines of Different Elements. (Recd. May 12. Read May 19.)	'Proc. Roy. Soc.' xxxii. 225–231; 'Beiblätter,' v. 741–742 (Abs.)
W. Crookes . .	Sur les spectres phosphorescents discontinus observés dans le vide presque parfait. (Read May 30.)	'C. R.' xcii. 1281–1283; 'Beiblätter,' v. 511–513 (Abs.)
E. Becquerel . .	Observations relatives à la communication précédente. (Read May 30.)	'C. R.' xcii. 1283; 'Beiblätter,' v. 511–513 (Abs.)

ABSORPTION SPECTRA.

1870.

L. Schönn . .	Ueber Blattgrün und Blumenblau. (May 10.)	'Zeitschr. anal. Chem.' ix. 327–328.
F. U. Daube . .	Ueber Curcumin, den Farbstoff der Curcumawurzel. ('N. Repert. Pharm.' xx. 36.)	'Ber.' iii. 609–613; 'J. Chem. Soc.' [2] ix. 152–154 (Abs.)

1871.

A. Weinhold . .	Zur Umkehrung der Natriumlinie. (Feb. 1871.)	'Ann. Phys. u. Chem.' cxlii. 321–323; 'Ann. Chim. et Phys.' [4] xxvi. 281–282 (Abs.); 'J. Chem. Soc.' [2] ix. 185–186 (Abs.); 'Phil. Mag.' [4] xli. 404; 'Arch. de Genève,' [2] xli. 63–64.
J. L. Soret . .	Observation sur la note précédente .	'Arch. de Genève,' [2] xli. 64–65.
A. Kundt . .	Ueber das Absorptionsspectrum der flüssigen Untersalpetersäure.	'Ann. Phys. u. Chem.' cxli. 157–159; 'Zeitschr. f. Chem.' [2] vii. 64 (Abs.); 'J. Chem. Soc.' [2] ix. 185 (Abs.)
J. J. Müller . .	Das Grün der Blätter . . .	'Ann. Phys. u. Chem.' cxlii. 615–616; 'J. Chem. Soc.' [2] ix. 654 (Abs.)
A. Cornu . .	Sur le renversement des raies spectrales des vapeurs métalliques. (Read July 31.)	'C. R.' lxxiii. 332–337; 'Phil. Mag.' [4] xlii. 237–240; 'J. Chem. Soc.' [2] ix. 1142–1144 (Abs.); 'Am. J.' [3] iii. 465 (Abs.)
T. Andrews . .	The Dichroism of the Vapour of Iodine.	'Chem. News,' xxiv. 75; 'J. Chem. Soc.' [2] ix. 993 (Abs.)

Absorption Spectra, 1871, 1872.

G. Campani . .	Carattere spettroscopico della soluzione ammoniacale di carminio, di cocciniglia e di altre sostanze.	'Gazz. Chim. Ital.' i. 471–472; 'J. Chem. Soc.' [2] ix. 1096 (Abs.)
A. Heynsius and J. F. F. Campbell.	Die Oxydationsproducte der Gallenfarbstoffe und ihre Absorptionsstreifen.	'Pflüger's Archiv f. Physiol.' iv. 497–547; 'J. Chem. Soc.' [2] x. 307–308 (Abs.)
H. C. Sorby . .	Blood Spectrum	'Nature,' iv. 505.
"	Correction. (Oct. 28) . . .	" v. 7.
J. Janssen . .	Sur le spectre de la vapeur d'eau .	'Ann. Chim. et Phys.' [4] xxiv. 215–217; 'J. Chem. Soc.' [2] x. 280 (Abs.)

1872.

L. Schönn . .	Ueber die Absorptionsstreifen des Blattgrüns. (Nov. 27, 1871.)	'Ann. Phys. u. Chem.' cxlv. 166–167; 'Arch. de Genève' [2] xliii. 282–283.
D. Gernez . .	Sur les raies d'absorption produites dans le spectre par les solutions des acides hypoazotique, hypochlorique et chloreux. (Read Feb. 12.)	'C. R.' lxxiv. 465–468; 'J. Chem. Soc.' [2] x. 280 (Abs.); 'Ber.' v. 218 (Abs.)
" . .	Spectres d'absorption du chlore et du chlorure d'iode. (Read Mar. 4.)	'C. R.' lxxiv. 660–662; 'J. Chem. Soc.' [2] x. 462–463 (Abs.); 'Phil. Mag.' [4] xliii. 318–320.
" . .	Sur les spectres d'absorption des vapeurs de soufre, d'acide sélénieux et d'acide hypochloreux. (Read Mar. 18.)	'C. R.' lxxiv. 803–805; 'J. Chem. Soc.' [2] x. 382 (Abs.); 'Am. J.' iv. 60 (Abs.)
B. J. Stokvis . .	A Reducible By-Product of the Oxidation of Bile Pigment. ('N. Repert. Pharm.' xxi. 123.)	'J. Chem. Soc.' [2] x. 308–309 (Abs.)
G. Salet . . .	Sur le spectre d'absorption de la vapeur de soufre. (Read Mar. 25.)	'C. R.' lxxiv. 865–866; 'J. Chem. Soc.' [2] x. 382 (Abs.); 'Ber.' v. 323 (Abs.)
D. Gernez . .	Sur les spectres d'absorption des vapeurs de sélénium, de protochlorure et de bromure de sélénium, de tellure, de protochlorure et protobromure de tellure, de protobromure d'iode et d'alizarine. (Read April 29.)	'C. R.' lxxiv. 1190–1192; 'J. Chem. Soc.' [2] x. 665 (Abs.); 'Phil. Mag.' [4] xliii. 473–475; 'Am. J.' iv. 59–60.
Vogel . . .	Ueber die Lichtwirkung verschieden gefärbter Blätter. (May 4.)	'Sitzungsb. Akad. München,' 1872, 133–137.
J. Chautard . .	Recherches sur les raies de la chlorophylle. (Read Dec. 30.)	'C. R.' lxxv. 1836–1839; 'J. Chem. Soc.' [2] xi. 341 (Abs.)
G. Kraus . . .	Zur Kenntniss der Chlorophyll-farbstoffe. (Stuttgart, 1872.)	'Arch. de Genève,' [2] xlvi. 359–362 (Abs.)

ABSORPTION SPECTRA, 1873, 1874.

1873.

W. H. Perkin . .	Absorption Spectra of Anthrapurpurin.	'J. Chem. Soc.' [2] xi. 433.
J. Chautard . .	Classification des bandes d'absorption de la chlorophylle; raies accidentelles. (Read May 19.)	'C. R.' lxxvi. 1273–1275; 'J. Chem. Soc.' [2] xi. 997–998 (Abs.)
H. C. Sorby . .	On Comparative Vegetable Chromatology. (Recd. June 9. Read June 19.)	'Proc. Roy. Soc.' xxi. 442–483; 'J. Chem. Soc.' [2] xii. 279–285 (Abs.)
H. Pocklington .	M. Chautard's Classification of the Absorption-Bands of Chlorophyll.	'Pharm. J. Trans.' [3] iv. 61–63.
J. Chautard . .	Recherches sur le spectre de la chlorophylle. (Read Sept. 8.)	'C. R.' lxxvii. 596–597; 'Ber.' vi. 1265 (Abs.); 'Phil. Mag.' [4] xlvi. 335–336; 'J. Chem. Soc.' [2] xi. 1258–1259 (Abs.)
H. Emsmann . .	Salpetersaure Nickellösung als Absorptionspräparat.	'Ann. Phys. u. Chem.' Ergänzungsband,' 1874, vi. 334–335; 'Phil. Mag.' [4] xlvi. 329–330; 'J. Chem. Soc.' [2] xii. 113.
W. N. Hartley. .	On the Optical Properties of a new Chromic Oxalate. (Recd. June 19. Read Nov. 27.)	'Proc. Roy. Soc.' xxi. 499–507; 'Ber.' vi. 1425 (Abs.)

1874.

K. Vierordt . .	Die graphische Darstellung der Absorptionsspectren. (Dec. 27, 1873.)	'Ann. Phys. u. Chem.' cli. 119–124.
W. N. Hartley. .	Preliminary Notice of Experiments concerning the Chemical Constitution of Saline Solutions. (Recd. Feb. 3. Read March 19.)	'Proc. Roy. Soc.' xxii. 241–243; 'Chem. News,' xxix. 148.
H. E. Roscoe and A. Schuster.	Note on the Absorption-Spectra of Potassium and Sodium at Low Temperatures. (Recd. April 30. Read June 11.)	'Proc. Roy. Soc.' xxii. 362–364; 'Chem. News,' xxix. 268–269; 'J. Chem. Soc.' [2] xii. 942 (Abs.); 'Am. J.' ix. 212–213.
W. Stein. . .	Zur Spectralanalyse gefärbter Flüssigkeiten und Gläser.	'J. pr. Chem.' [2] ix. 383–384; 'J. Chem. Soc.' [2] xiii. 412–414 (Abs.)
J. N. Lockyer . .	Spectroscopic Notes. No. I. On the Absorption of Great Thicknesses of Metallic and Metalloidal Vapours. (Recd. April 20. Read June 11.)	'Proc. Roy. Soc.' xxii. 371–372; 'Phil. Mag.' [4] xlix. 233–235.
" . .	Spectroscopic Notes. No. II. On the Evidence of Variation in Molecular Structure. (Recd. May 26. Read June 11.)	'Proc. Roy. Soc.' xxii. 372–374; 'Ann. Phys. u. Chem.' clv. 136–140; 'Phil. Mag.' [4] xlix. 235–237; 'J. Chem. Soc.' 1876, ii. 34 (Abs.)

ABSORPTION SPECTRA, 1874, 1875.

J. N. Lockyer . .	Spectroscopic Notes. No. III. On the Molecular Structure of Vapours in connection with their Densities. (Recd. May 26. Read June 11.)	'Proc. Roy. Soc.' xxii. 374–378; 'Ann. Phys. u. Chem.' clv. 140–146; 'Phil. Mag.' [4] xlix. 320–326; 'J. Chem. Soc.' 1876, i. 181.
" . .	Spectroscopic Notes. No. IV. On a New Class of Absorption Phenomena. (Recd. May 26. Read June 11.)	'Proc. Roy. Soc.' xxii. 378–380.
H. Behrens . .	Ueber das Spectrum des Edelopals.	'Jahrb. f. Mineral.' 1873, 920–931.
J. Chautard . .	Recherches sur le spectre de la chlorophylle.	'Ann. Chim. et Phys.' [5] iii. 5–56; 'J. Chem. Soc.' [2] xiii. 171–172 (Abs.)
Pringsheim . .	Ueber die Absorptionsspectra der Chlorophyll - farbstoffe. (Read Oct. 22.)	'Monatsb. Berl. Akad.' 1874, 628–659.
W. Stein . . .	Zur Spectralanalyse gefärbter Flüssigkeiten, Gläser und Dämpfe.	'J. pr. Chem.' [2] x. 368–384; 'J. Chem. Soc.' [2] xiii. 412–414 (Abs.)

1875.

J. N. Lockyer and W. C. Roberts.	On the Absorption Spectra of Metals volatilised by the Oxyhydrogen Flame. (Recd. Feb. 4. Read Mar. 18.)	'Proc. Roy. Soc.' xxiii. 344–349; 'Phil. Mag.' [5] i. 234–239; 'J. Chem. Soc.' 1876, ii. 156–157 (Abs.)
W. N. Hartley. .	On the Action of Heat on the Absorption Spectra and Chemical Constitution of Saline Solutions. (Recd. March 10. Read April 22.)	'Proc. Roy. Soc.' xxiii. 372–373 (Abs.); 'Ber.' viii. 765 (Abs.); 'Phil. Mag.' [5] i. 244–245.
R. Bunsen . .	Spectralanalytische Untersuchungen.	'Ann. Phys. u. Chem.' clv. 230–252, 366–384; 'Phil. Mag.' [4] l. 417–430, 527–539; 'J. Chem. Soc.' 1876, i. 665–667 (Abs.)
G. Francis . .	Spectrum of Fish Pigment. (Oct. 9)	'Nature,' xiii. 167.
H. W. Vogel . .	Ueber die Absorptionsspectra verschiedener Farbstoffe, sowie über die Anwendung derselben zur Entdeckung von Verfälschungen. (Sept. 1875. Read Oct. 11.)	'Ber.' viii. 1246–1254; 'Dingl. J.' ccxix. 73–81.
H. W. Vogel . .	Ueber die Absorptionsspectren einiger Salze der Metalle der Eisengruppe und ihre Anwendung in der Analyse. (Read Nov. 22.)	'Ber.' viii. 1533–1540; 'J. Chem. Soc.' 1876, i. 739–740 (Abs.); 'Dingl. J.' ccxix. 532–538.
" . .	Spectroskopische Untersuchung des Lichts der blauen Grotte auf Capri. (July 1875.)	'Ann. Phys. u. Chem.' clvi. 325–326; 'Am. J.' [3] xi. 56–57.
H. Bührig . .	Das Absorptionsspectrum des Didyms. (May 1875.)	'J. pr. Chem.' [2] xii. 209–215; 'Am. J.' [3] xi. 142 (Abs.)
Pringsheim . .	Ueber natürliche Chlorophyllmodificationen und die Farbstoffe der Florideen. (Read Dec. 2.)	'Monatsb. Berl. Akad.' 1875, 745–759.

ABSORPTION SPECTRA, 1876–1878.

1876.

J. Wunder . . .	Ueber die Absorptionsspectren verschiedener Ultramarinsorten. (Feb. 1876. Read Feb. 28.)	'Ber.' ix. 295–299; 'J. Chem. Soc.' 1876, i. 864–865.
R. Hoffmann . .	Bemerkung zu J. Wunder's Mittheilung über die Absorptionsspectren verschiedener Ultramarinsorten. (Mar. 22.)	'Ber.' ix. 494–495.
W. Ackroyd . .	Selective Absorption. (Read April 28.)	'Proc. Phys. Soc.' ii. 110–118; 'Phil. Mag.' [5] ii. 423–430; 'J. Chem. Soc.' 1877, i. 571–572 (Abs.); 'Beiblätter,' i. 350–352 (Abs.)
H. E. Roscoe and T. E. Thorpe.	On the Absorption-Spectra of Bromine and of Iodine Monochloride. (Recd. Mar. 16. Read May 4.)	'Phil. Trans.' 1877, clxvii. 207–212; 'Proc. Roy. Soc.' xxv. 4 (Abs.); 'Beiblätter,' ii. 256–258.
Sir J. Conroy . . .	Absorption-Spectra of Iodine. (Recd. April 12. Read May 18.)	'Proc. Roy. Soc.' xxv. 46–51; 'Phil. Mag.' [5] iii. 68–73.
W. Ackroyd . .	Metachromism, or Colour-change .	'Chem. News,' xxxiv. 75–77.

1877.

J. Moser . . .	Die Spectren der chemischen Verbindungen.	'Ann. Phys. u. Chem.' clx. 177–199; 'J. Chem. Soc.' 1877, ii. 688–690 (Abs.); 'Nature,' xvi. 193–194 (Abs.)
" . . .	Die Spectren der salpetrigen und der Untersalpeter-Säure.	'Ann. Phys. u. Chem.' N.F. ii. 139–140.
C. Günther . .	Ueber ein einfaches Verfahren, die Umkehrung der farbigen Linien der Flammenspectra, insbesondere der Natriumlinie, subjectiv darzustellen. (July 7.)	'Ann. Phys. u. Chem.' N.F. ii. 477–478; 'J. Chem. Soc.' xxxiv. 463 (Abs.)
W. Ackroyd . .	Transverse Absorption of Light .	'Chem. News,' xxxvi. 159–161; 'J. Chem. Soc.' xxxiv. 101 (Abs.)
" . .	Reversal of the Sodium Lines. (Oct. 1.)	'Chem. News,' xxxvi. 164–165.
F. von Lepel . .	Spectralanalytische Notizen. (Oct. 1877.)	'Ber.' x. 1875–1877; 'J. Chem. Soc.' xxxiv. 168 (Abs.)

1878.

J. L. Soret . . .	Sur les spectres d'absorption ultra-violets des différents liquides.	'Arch. de Genève,' [2] lx. 298–300; 'Beiblätter,' ii. 30–31 (Abs.)
A. Rosenstiehl .	L'alizarine nitrée	'Ann. Chim. et Phys.' [5] xii. 519–529; 'J. Chem. Soc.' xxxiv. 231–232 (Abs.)

ABSORPTION SPECTRA, 1878.

A. Jäderholm . .	Untersuchungen über den Blutfarbstoff und seine Derivate.	'Zeitschr. f. Biol.' xiii. 193–255; 'J. Chem. Soc.' xxxiv. 236–237 (Abs.)
E. Brücke . .	Ueber das Absorptionsspektrum des übermangansauren Kalis und seine Benutzung bei chemisch-analytischen Arbeiten.	'Chem. Centr.' 1877, viii. 139–143; 'J. Chem. Soc.' xxxiv. 242–243 (Abs.)
P. Glan . . .	Ueber den Einfluss der Dichtigkeit eines Körpers auf die Menge des von ihm absorbirten Lichtes. (Oct. 28, 1877.)	'Ann. Phys. u. Chem.' N.F. iii. 54–82.
G. D. Liveing and J. Dewar.	On the Reversal of the Lines of Metallic Vapours. No. I. (Read Feb. 28.)	'Proc. Roy. Soc.' xxvii. 132–136; 'Beiblätter,' ii. 261–263 (Abs.)
F. Claes . . .	Ueber die Veränderlichkeit der Lage der Absorptionsstreifen. (Aug. 1877.)	'Ann. Phys. u. Chem.' N.F. iii. 389–414.
J. L. Soret . .	Recherches sur l'absorption des rayons ultra-violets par diverses substances.	'Arch. de Genève' [2] lxi. 322–359; 'C. R.' lxxxvi. 708–711; 'J. Chem. Soc.' xxxiv. 629 (Abs.); 'Beiblätter,' ii. 347–350 (Abs.)
C. Liebermann. .	Ueber die Färbungen der Vogeleierschalen. (Read Mar. 25.)	'Ber.' xi. 606–610; 'Am. J.' [3] xvi. 66 (Abs.)
H. W. Vogel . .	Ueber die Wandlung der Spectren verschiedener Farbstoffe. (Mar. 1878. Read Mar. 25.)	'Ber.' xi. 622–624; 'J. Chem. Soc.' xxxiv. 545 (Abs.)
J. L. Soret . .	Sur les spectres d'absorption ultra-violets des terres de la gadolinite. (Read April 29.)	'C. R.' lxxxvi. 1062–1064; 'Beiblätter,' ii. 410–411 (Abs.)
G. D. Liveing and J. Dewar.	On the Reversal of the Lines of Metallic Vapours. No. II. (Recd. Mar. 26. Read May 2.)	'Proc. Roy. Soc.' xxvii. 350–354; 'Beiblätter,' ii. 490–492.
H. W. Vogel . .	Untersuchungen über Absorptionsspectra. (Read May 20.)	'Monatsb. Berl. Akad.' 1878, 409–431.
H. W. Vogel . .	Ueber die Verschiedenheit der Absorptionsspektra eines und desselben Stoffs. (May 1 and June 25.)	'Ber.' xi. 913–920, 1363–1371; 'J. Chem. Soc.' xxxvi. 189 (Abs.); 'Beiblätter,' ii. 699–702 (Abs.)
F. v. Lepel . .	Ueber die Aenderung der Absorptionsspectra einiger Farbstoffe in verschiedenen Lösungsmitteln. (April 1878. Read May 27.)	'Ber.' xi. 1146–1151; 'J. Chem. Soc.' xxxiv. 925–926 (Abs.); 'Beiblätter,' iii. 360–361 (Abs.)
G. D. Liveing and J. Dewar.	On the Reversal of the Lines of Metallic Vapours. No. III. (Recd. June 19. Read June 20.)	'Proc. Roy. Soc.' xxvii. 494–496; 'Beiblätter,' ii. 601 (Abs.)
H. W. Vogel . .	Zur Kenntniss der Alizarin-Farbstoffe und grünen Anilinfarben. (June 25.)	'Ber.' xi. 1371–1374; 'J. Chem. Soc.' xxxvi. 83–85 (Abs.)
A. Kundt . .	Ueber den Einfluss des Lösungsmittels auf die Absorptionsspectra gelöster absorbirender Medien. (Read July 7.)	'Sitzungsb. Akad. München,' 1877, 234–262; 'Ann. Phys. u. Chem.' N.F. iv. 34–54.

ABSORPTION SPECTRA, 1878, 1879.

J. Moser . . .	Bemerkung zur Abhandlung des Hrn. Hermann W. Vogel: Ueber die Verschiedenheit der Absorptionsspectra eines und desselben Stoffes. (July 8.)	'Ber.' xi. 1416–1417; 'J. Chem. Soc.' xxxiv. 829 (Abs.)
H. W. Vogel . .	Ueber die Verschiedenheit der Absorptionsspectra eines und desselben Stoffes. Antwort auf die Bemerkungen des Hrn. J. Moser. (July 29.)	'Ber.' xi. 1562–1563.
J. Landauer . .	Zur Kenntniss der Absorptionsspectra. I. Das Safranin. (Oct. 8. Read Oct. 14.)	'Ber.' xi. 1772–1775; 'J. Chem. Soc.' xxxvi. 101 (Abs.); 'Beiblätter,' iii. 195–196 (Abs.)
G. D. Liveing and J. Dewar.	Studies in Spectrum Analysis. (Read Nov. 4.)	'Proc. Phil. Soc. Camb.' iii. 208–209; 'Nature,' xix. 163–164.
Sir J. Conroy . .	On the Light Reflected by Potassium Permanganate.	'Proc. Phys. Soc.' ii. 340–344; 'Phil. Mag.' [5] vi. 454–458; 'J. Chem. Soc.' xxxvi. 425 (Abs.)
J. L. Schönn . .	Ueber die Absorption des Lichts durch Wasser, Steinöl, Ammoniak, Alcohol und Glycerin.	'Ann. Phys. u. Chem.' Ergänzungsb.' 1878, viii. 670–675; 'J. Chem. Soc.' xxxiv. 693 (Abs.)
J. L. Soret . .	Recherches sur l'absorption des rayons ultra-violets par diverses substances. II. Sur les spectres d'absorption des terres de la gadolinite et du didyme.	'Arch. de Genève,' [2] lxiii. 89–112; 'C. R.' lxxxvi. 1062–1064; 'Beiblätter,' iii. 196–197 (Abs.)

1879.

A. Riccò . . .	Studî spettrali sul colore delle acque, nota seconda.	'Mem. spettr. ital.' viii. 1–10.
W. N. Hartley and A. K. Huntington.	Researches on the Action of Organic Substances on the Ultra-violet Rays of the Spectrum. (Recd. Oct. 10, 1878. Read Jan. 9, 1879.)	'Phil. Trans.' 1879, clxx. 257–274; 'Proc. Roy. Soc.' xxviii. 233–236 (Abs.); 'J. Chem. Soc.' xxxviii. 430 (Abs.); 'Beiblätter,' iii. 357–358 (Abs.)
C. Liebermann .	Ueber die der Chrysazinreihe angehörigen Anthracenverbindungen. (Read Jan. 27.)	'Ber.' xii. 182–188: 'J. Chem. Soc.' xxxvi. 537–538 (Abs.)
G. D. Liveing and J. Dewar.	On the Reversal of the Lines of Metallic Vapours. No. IV. (Recd. Feb. 12. Read Feb. 20.)	'Proc. Roy. Soc.' xxviii. 352–358; 'Beiblätter,' iii. 502–504 (Abs.)
G. D. Liveing and J. Dewar.	On the Reversal of the Lines of Metallic Vapours. No. V. (Recd. Feb. 20. Read Feb. 27.)	'Proc. Roy. Soc.' xxviii. 367–372; 'Beiblätter,' iii. 502–504 (Abs.)
A. Meyer . .	Absorption Spectra of Brucine, Morphine, Strychnine, Veratrine, and Santonine in Concentrated Acids. ('Arch. Pharm.' [3] xiii. 413–416.)	'J. Chem. Soc.' xxxvi. 269.

Absorption Spectra, 1879, 1880.

J. L. Soret	Sur les spectres d'absorption du didyme et de quelques autres substances extraites de la samarskite. (Read Mar. 3.)	'C. R.' lxxxviii. 422–424.
A. Hilger and H. Bischoff.	Colouring Matter of the Caryophyllaceæ.	'Landw. Versuchs-Stat.' xxiii. 456–461; 'J. Chem. Soc.' xxxvi. 730–731 (Abs.)
J. L. Schönn	Über die Absorption des Lichtes durch Flüssigkeiten.	'Ann. Phys. u. Chem.' N.F. vi. 267–270.
J. N. Lockyer	Note on some Phenomena attending the Reversal of Lines. (Recd. Mar. 5. Read Mar. 20.)	'Proc. Roy. Soc.' xxviii. 428–432; 'Beiblätter,' iii. 608–609 (Abs.)
G. D. Liveing and J. Dewar.	On the Reversal of the Lines of Metallic Vapours. No. VI. (Recd. Mar. 27. Read April 3.)	'Proc. Roy. Soc.' xxviii. 471–475; 'Beiblätter,' iii. 710 (Abs.)
J. L. Smith and Lecoq de Boisbaudran.	Sur le spectre du nitrate de didyme. (Read June 9.)	'C. R.' lxxxviii. 1167; 'J. Chem. Soc.' xxxvi. 861–862 (Abs.); 'Ber.' xii. 2080 (Abs.); 'Beiblätter,' iii. 792 (Abs.)
Lecoq de Boisbaudran.	Sur le spectre du nitrate d'erbium. (Read June 9.)	'C. R.' lxxxviii. 1167–1168; 'J. Chem. Soc.' xxxvi. 862 (Abs.); 'Ber.' xii. 2080 (Abs.); 'Beiblätter,' iii. 792 (Abs.)
A. Cornu	Sur l'absorption par l'atmosphère des radiations ultra-violettes. (Read June 23.)	'C. R.' lxxxviii. 1285–1290; 'Beiblätter,' iv. 40–41 (Abs.)
J. L. Soret and A. A. Rilliet.	Sur les spectres d'absorption ultra-violets des éthers azotiques et azoteux. (Read Nov. 3.)	'C. R.' lxxxix. 747–749; 'J. Chem. Soc.' xxxviii. 202 (Abs.); 'Beiblätter,' iv. 278–280 (Abs.)
W. N. Hartley and A. K. Huntington.	Researches on the Action of Organic Substances on the Ultra-violet Rays of the Spectrum. Part III. An Examination of Essential Oils. (Recd. July 22. Read Nov. 20.)	'Proc. Roy. Soc.' xxxi. 1–26, xxix. 290–292 (Abs.); 'Chem. News,' xl. 269–270, 'J. Chem. Soc.' xxxviii. 201 (Abs.); 'Beiblätter,' iv. 370–371 (Abs.), v. 47–48 (Abs.); 'Ber.' xiv. 501–503 (Abs.)
G. D. Liveing and J. Dewar.	On the Reversal of the Lines of Metallic Vapours. No. VII. (Recd. Nov. 18. Read Nov. 27.)	'Proc. Roy. Soc.' xxix. 402–406; 'Beiblätter,' iv. 364–366 (Abs.)
	1880.	
C. A. Young	Re-reversal of Sodium Lines. (Jan. 5.)	'Nature,' xxi. 274–275; 'Beiblätter,' iv. 370 (Abs.)
Piazzi Smyth	Three Years' Experimenting in Mensurational Spectroscopy.	'Nature,' xxii. 193–195, 222–225.
J. L. Soret	Sur les spectres d'absorption des métaux faisant partie des groupes de l'yttria et de la cérite.	'C. R.' xci. 378–381; 'J. Chem. Soc.' xl. 349 (Abs.); 'Chem. Centr.' 1880, 662 (Abs.); 'Beiblätter,' v. 124–125 (Abs.)

ABSORPTION SPECTRA, 1880, 1881—PHYSICAL RELATIONS, 1871.

J. L. Soret . .	Recherches sur l'absorption des rayons ultra-violets par diverses substances. III. Nouvelle étude des spectres d'absorption des métaux terreux.	'Arch. de Genève' [3] iv. 261–292; 'Beiblätter,' v. 124–125 (Abs.)
W. J. Russell and W. Lapraik.	On the Absorption Bands in certain Colourless Liquids.	'Nature,' xxii. 368–370; 'Beiblätter,' v. 44–45 (Abs.)
W. J. Russell . . .	On the Absorption Spectra of Cobalt Salts. (Recd. Aug. 4. Read Nov. 18.)	'Proc. Roy. Soc.' xxxii. 258–272; xxxi. 51–54 (Abs.); 'Beiblätter,' v. 126 (Abs.); 'Ber.' xiv. 503 (Abs.); 'Chem. News,' xliii. 27–28 (Abs.); 'J. Chem. Soc.' xl. 486–487 (Abs.)
J. Chappuis . .	Sur le spectre d'absorption de l'ozone. (Read Dec. 13.)	'C. R.' xci. 985–986; 'J. Chem. Soc.' xl. 213 (Abs.); 'Beiblätter,' v. 123 (Abs.); 'Ber.' xiv. 105 (Abs.)

1881.

W. N. Hartley. .	On the Absorption Spectrum of Ozone.	'J. Chem. Soc.' xxxix. 57–60; 'Ber.' xiv. 672 (Abs.); 'Beiblätter,' v. 505–506 (Abs.)
J. Landauer . .	Zur Kenntniss der Absorptions-spectra. (Feb. 18.)	'Ber.' xiv. 391–394; 'J. Chem. Soc.' xl. 591 (Abs.); 'Beiblätter,' v. 441 (Abs.)
W. N. Hartley. .	On the Absorption of Solar Rays by Atmospheric Ozone. Part I.	'J. Chem. Soc.' xxxix. 111–128; 'Ber.' xiv. 1390 (Abs.); 'Beiblätter,' v. 505 (Abs.)
W. J. Russell and W. Lapraik.	On Absorption Bands in the Visible Spectrum produced by certain Colourless Liquids.	'J. Chem. Soc.' xxxix. 168–173.
D. Gernez . .	Note sur le prétendu spectre d'absorption spécial de l'acide azoteux.	'Bull. Soc. Philom.' [7] v. 42.
G. D. Liveing and J. Dewar.	Note on the Reversal of the Spectrum of Cyanogen. (Read July 7.)	'Proc. Roy. Soc.' xxxiii. 3–4.

PHYSICAL RELATIONS.

1871.

A. Kundt . .	Ueber die anomale Dispersion der Körper mit Oberflächenfarben. (Jan. 6.)	'Ann. Phys. u. Chem.' cxlii. 163–171; 'Ann. Chim. et Phys.' [4] xxv. 404–409 (Abs.)
J. Stefan. . .	Ueber den Einfluss der Wärme auf die Brechung des Lichtes in festen Körpern. (Read Feb. 3.)	'Sitzungsb. Wien. Akad.' lxiii. II. 223–245.

PHYSICAL RELATIONS, 1871.

A. Kundt . .	Nachtrag zum Aufsatz: Ueber die anomale Dispersion der Körper mit Oberflächenfarben. (April 26.)	'Ann. Phys. u. Chem.' cxliii. 149–152; 'Ann. Chim. et Phys.' [4] xxv. 409–410 (Abs.)
M. Croullebois. .	Nouvelle méthode de détermination des indices de réfraction des liquides.	'Ann. Chim. et. Phys.' [4] xxii. 139–150.
C. Christiansen .	Ueber die Brechungsverhältniss des Fuchsins. (Read Feb. 17.)	'Oversigt k. Danske Vidensk. Selskabs.' 1871, 5–17; 'Ann. Phys. u. Chem.' cxliii. 250–259; 'Ann. Chim. et Phys.' [4] xxv. 400–403 (Abs.)
C. Schultz-Sellack .	Chemische und mechanische Veränderung der Silber-Haloidsalze durch Licht. (Recd. April 7.)	'Ber.' iv. 343–345; 'Phil. Mag.' [4] xli. 550–552.
A. Kundt . .	Ueber anomale Dispersion. (May 28.)	'Ann. Phys. u. Chem.' cxliii. 259–269; 'Ann. Chim. et Phys.' [4] xxv. 413–418 (Abs.)
V. von Lang . .	Ueber die anomale Dispersion spitzer Prismen. (Read April 27.)	'Sitzungsber. d. Wien. Akad.' lxiii. II. 658–660; 'Ann. Phys. u. Chem.' cxliii. 269–272; 'Ann. Chim. et Phys.' [4] xxv. 410–411 (Abs.)
W. Sellmeier . .	Zur Erklärung der abnormen Farbenfolge im Spectrum einiger Substanzen.	'Ann. Phys. u. Chem.' cxliii. 272–282; 'Ann. Chim. et Phys.' [4] xxv. 421–422.
A. Crova . . .	Sur les phénomènes d'interférence produits par les réseaux parallèles. (Read June 26.)	'C. R.' lxxii. 855–858.
C. Schultz-Sellack .	Ueber die chemische und mechanische Veränderung der Silberhaloïdsalze durch das Licht.	'Ann. Phys. u. Chem.' cxliii. 439–449.
J. L. Soret . .	Sur la dispersion anormale de quelques substances.	'Arch. de Genève' [2] xl. 280–283; 'Ann. Phys. u. Chem.' cxliii. 325–327; 'Phil. Mag.' [4] xliv. 395–396; 'Ann. Chim. et Phys.' [4] xxv. 412–413 (Abs.)
E. Lommel . .	Erythroskop und Melanoskop .	'Ann. Phys. u. Chem.' cxliii. 483–490.
S. Lamansky . .	Ueber die Gränzen der Empfindlichkeit des Auges für Spectralfarben. (July 1870.)	'Ann. Phys. u. Chem.' cxliii. 633–643.
P. Blaserna . .	Déplacement des raies du spectre sous l'action de la température du prisme.	'Arch. de Genève' [2] xli. 429–430; 'Ann. Phys. u. Chem.' cxliii. 655–656; 'J. Chem. Soc.' [2] x. 118 (Abs.); 'Phil. Mag.' [4] xliii. 239–240.

PHYSICAL RELATIONS, 1871–1873.

A. Kundt . .	Ueber anomale Dispersion (III. Mittheilung). (Aug. 29.)	'Ann. Phys. u. Chem.' cxliv. 128–137; 'Ann. Chim. et Phys.' [4] xxv. 418–419 (Abs.)
Lecoq de Boisbaudran.	Observations sur quelques points d'analyse spectrale, et sur la constitution des étincelles électriques. (Read Oct. 16.)	'C. R.' lxxiii. 943–946; 'J. Chem. Soc.' [2] x. 117 (Abs.)
S. Lamansky . .	Ueber das Wärmespectrum des Sonnen- und Kalklichtes. (Read Dec. 7.)	'Monatsb. Berl. Akad.' 1871, 632–641; 'Phil. Mag.' [4] xliii. 282–289.

1872.

J. H. Gladstone .	On Essential Oils. Part II. . .	'J. Chem. Soc.' [2] x. 1–12; 'Ber.' v. 60 (Abs.)
A. Kundt . .	Ueber anomale Dispersion (IV. Mittheilung). (Nov. 1871.)	'Ann. Phys. u. Chem.' cxlv. 67–80; 'Ann. Chim. et Phys.' [4] xxv. 419–421.
" . .	Nachtrag zur vierten Mittheilung über anomale Dispersion.	'Ann. Phys. u. Chem.' cxlv. 164–166.
A. Crova . . .	Sur les phénomènes d'interférence produits par les réseaux parallèles. (Read April 1.)	'C. R.' lxxiv. 932–936.
G. Quincke . .	Optische Experimentaluntersuchungen. Ueber Beugungsgitter. (Christmas, 1871.)	'Ann. Phys. u. Chem.' cxlvi. 1–65.
C. Christiansen .	Zur Farbenzerstreuung des Fuchsins.	'Ann. Phys. u. Chem.' cxlvi. 154–155; 'J. Chem. Soc.' [2] xi. 236.
M. Sekulić . .	Ultraviolette Strahlen sind unmittelbar sichtbar.	'Ann. Phys. u. Chem.' cxlvi. 157–158; 'J. Chem. Soc.' [2] xi. 125 (Abs.)
S. Lamansky . .	Untersuchungen über das Wärmespectrum des Sonnen- und Kalklichtes. (Feb. 1872.)	'Ann. Phys. u. Chem.' cxlvi. 200–232.
E. Mach . . .	Spectrale Untersuchung eines longitudinaltönenden Glasstabes.	'Ann. Phys. u. Chem.' cxlvi. 316–317.
E. Wiedemann .	Ueber die Brechungsexponenten der geschwefelten Substitutionsproducte des Kohlensäureäthers.	'J. pr. Chem.' [2] vi. 453–455.

1873.

J. Tyndall . .	Effect of Resistance in modifying Spectra.	'Nature,' vii. 384.
Mousson . . .	Une méthode pour mesurer la dispersion dans les différentes parties du spectre fourni par un prisme ou un spectroscope quelconque.	'Arch. de Genève' [2] xlv. 13; 'Ann. Phys. u. Chem.' cxlviii. 660.
A. Secchi . .	Sur quelques observations spectroscopiques particulières. (Read April 28.)	'C. R.' lxxvi. 1052–1056.

PHYSICAL RELATIONS, 1873, 1874.

G. Quincke . .	On Diffraction	'Phil. Mag.' [4] xlv. 365–371.
E. Mach . . .	Historische Bemerkung betreffend das von Hrn. Mousson angegebene Verfahren zur Untersuchung der Dispersion.	'Ann. Phys. u. Chem.' cxlix. 270.
G.W. Royston-Pigott	Researches in Circular Solar Spectra applied to test Residuary Aberration in Microscopes and Telescopes, and the Construction of a Compensating Eyepiece, being a sequel to the paper on a Searcher for Aplanatic Images. (Recd. April 24. Read June 19.)	'Proc. Roy. Soc.' xxi. 426–442.
O. N. Rood . .	On a Secondary Spectrum of very large size, with a Construction for Secondary Spectra. (July 11.)	'Am. J.' [3] vi. 172–180.
G. Quincke . .	Optische Experimental-Untersuchungen. Ueber das Verhalten des polarisirten Lichtes bei der Beugung. (March 15.)	'Ann. Phys. u. Chem.' cxlix. 273–324.
E. Becquerel . .	Sur la détermination des longueurs d'onde des rayons de la partie infra-rouge du spectre, au moyen des effets de phosphorescence. (Read Aug. 4.)	'C. R.' lxxvii. 302–304.
J. Dewar . .	Measurement of High Temperatures	'Chem. News,' xxviii. 174.
H. Behrens . .	Ueber die Entstehung von farbigem Licht durch elective Reflexion.	'Ann. Phys. u. Chem.' cl. 303–311.
H. Vogel . . .	Ueber die fortsetzenden Strahlen Becquerel's. (Oct. 20.)	'Ber.' vi. 1498–1501; 'J. Chem. Soc.' [2] xii. 332 (Abs.); 'Am. J.' vii. 508–509 (Abs.)

1874.

E. Ketteler . .	Das specifische Gesetz der sogenannten anomalen Dispersion. (Sept. 1873.)	'Ann. Phys. u. Chem.' Jubelband, 166–182.
A. Kundt . .	Ueber einige Beziehungen zwischen der Dispersion und Absorption des Lichtes.	'Ann. Phys. u. Chem.' Jubelband, 615–624.
P. Desains . .	Recherches expérimentales sur les anneaux colorés de Newton. (Read Jan. 26.)	'C. R.' lxxviii. 219–221; 'Phil. Mag.' [4] xlvii. 236–237.
H. Draper . .	Sur les longueurs d'onde et les caractères des raies violettes et ultra-violettes du Soleil, données par une photographie faite au moyen d'un réseau. (Read March 9.)	'C. R.' lxxviii. 682–686.
Mascart . . .	Sur la réfraction des gaz. (March 2.)	'C. R.' lxxviii. 617–621; 'Am. J.' [3] vii. 591–592 (Abs.); 'Ann. Phys. u. Chem.' cliii. 149–153.

PHYSICAL RELATIONS, 1874, 1875.

Mascart . . .	Sur la dispersion des gaz. (Read March 9.)	'C. R.' lxxviii. 679–682; 'Am. J.' [3] vii. 591–592 (Abs.)
" . . .	Sur la réfraction de l'eau comprimée. (March 23.)	'C. R.' lxxviii. 801–805; 'Am. J.' [3] vii. 593; 'Ann. Phys. u. Chem.' cliii. 154–158.
A. Crova . .	Sur les phénomènes d'interférence produits par les réseaux parallèles.	'Ann. Chim. et Phys.' [5] i. 407–432.
W. Spottiswoode .	On Combinations of Colour by means of Polarised Light. (Recd. April 8. Read May 21.)	'Proc. Roy. Soc.' xxii. 354–358.
L. Ranvier . .	Du spectre musculaire. (Read June 1.)	'C. R.' lxxviii. 1572–1575.
Terquem and Trannin	Méthode nouvelle pour déterminer l'indice de réfraction des liquides. (Read June 29.)	'C. R.' lxxviii. 1843–1845; 'Dingl. J.' ccxv. 552–554.
E. Wiedemann .	Ueber das von übermangansaurem Kali reflectirte Licht. (Read July 26.)	'Ber. d. K. Sächs. Ges.' xxv. 367–370; 'Ann. Phys. u. Chem.' cli. 625–628; 'Phil. Mag.' [4] xlviii. 231–233; 'J. Chem. Soc.' [2] xiii. 120 (Abs.)
V. v. Lang . .	Ueber die Abhängigkeit des Brechungsquotienten der Luft von der Temperatur.	'Sitzungsb. d. Wien. Akad.' lxix. II. 451–468; 'Ann. Phys. u. Chem.' cliii. 448–465.
G. Salet . . .	Sur la distribution des bandes dans les spectres primaires. (Read Nov. 20.)	'Bull. Soc. Chim.' [2] xxii. 543–545.

1875.

G. Pisati and E. Paterno.	Misura dell' indice di rifrazione del cimene, della benzina e di alcuni derivati del timol naturale e del timol sintetico. (Oct. 1874.)	'Gazz. Chim. Ital.' iv. 557–564; Ber.' viii. 71 (Abs.)
J. L. Hoorweg .	Ueber den Gang der Lichtstrahlen durch ein Spectroskop. (Sept. 1874.)	'Ann. Phys. u. Chem.' cliv. 423–444.
M. Carey Lea . .	On the Influence of Colour upon Refraction of Light. (March 20.)	'Am. J.' [3] ix. 355–357.
Wolcott Gibbs .	Optical Notices. 1. On a New Optical Constant; 2. On a Method of Measuring Refractive Indices without the use of Divided Instruments. (April 13.)	'Proc. Am. Acad.' x. 401–416; 'Ann. Phys. u. Chem.' clvi. 120–144.
J. Chautard . . .	Action des aimants sur les gaz raréfiés renfermés dans des tubes capillaires et illuminés par un courant induit. (Read May 3.)	'C. R.' lxxx. 1161–1164.
" . .	Phénomènes magnéto-chimiques produits au sein des gaz raréfiés dans les tubes de Geissler, illuminés à l'aide de courants induits. (Read July 12.)	'C. R.' lxxxi. 75–77; 'J. Chem. Soc.' 1876, i. 29 (Abs.)

Physical Relations, 1875, 1876.

W. Wernicke . .	Ueber die Absorption und Brechung des Lichtes in metallisch undurchsichtigen Körpern. (Read Nov. 19.)	'Monatsb. Berl. Akad.' 1874, 728–737; 'Ann. Phys. u. Chem.' clv. 87–95.
G. Lundquist . .	Om Värmefördelningen i Normalspektrum (Ueber die Wärmevertheilung im Normalspectrum).	'Oefversigt af K. Vetensk. Acad. Hand.' 1874, xxxi. X. 19–27; 'Ann. Phys. u. Chem.' clv. 146–155.
P. Desains and Aymonet.	Étude des bandes froides des spectres obscurs. (Read Sept. 6.)	'C. R.' lxxxi. 423–425; 'Am. J.' [3] x. 474–475 (Abs.); 'Phil. Mag.' [4] l. 331–333; 'J. Chem. Soc.' 1876, i. 27 (Abs.); 'Ann. Phys. u. Chem.' clvi. 174–176.
L. Sauer . . .	Experimente über die Sichtbarkeit ultravioletter Strahlen.	'Ann. Phys. u. Chem.' clv. 602–615.
Croullebois . .	Sur le pouvoir rotatoire du quartz dans le spectre ultra-violet. (Read Oct. 18.)	'C. R.' lxxxi. 666–667.
J. L. Soret . .	Sur les phénomènes de diffraction produits par les réseaux circulaires.	'Arch. de Genève,' [2] lii. 320–337; 'Ann. Phys. u. Chem.' clvi. 99–113.

1876.

G. G. Stokes . .	D-line Spectra	'Nature,' xiii. 247.
J. Loudon . .	Recomposition of the Component Colours of White Light. (Jan. 13.)	'Phil. Mag.' [5] i. 170–171.
Terquem and Trannin.	Méthode nouvelle pour déterminer rapidement l'indice de réfraction des liquides.	'J. de Phys.' iv. 232–238; 'Ann. Phys. u. Chem.' clvii. 302–309.
J. Chautard . .	Actions magnétiques exercées sur les gaz raréfiés des tubes de Geissler. (Read Jan. 24.)	'C. R.' lxxxii. 272–274.
J. L. Soret . .	Sur les phénomènes de diffraction produits par les réseaux circulaires.	'Ann. Chim. et Phys.' [5] vii. 409–424.
Aymonnet . .	Sur les spectres calorifiques. (Read May 15.)	'C. R.' lxxxii. 1153–1156; 'J. Chem. Soc.' 1876, ii. 374 (Abs.); 'Phil. Mag.' [5] ii. 158–160.
Gouy . . .	Recherches photométriques sur les flammes colorées. (Read July 24.)	'C. R.' lxxxiii. 269–272; 'Phil. Mag.' [5] ii. 317–319.
E. Wiedemann .	Methoden zur Bestimmung der Brechungsexponenten von Flüssigkeiten und Glasplatten. (Feb. 76.)	'Ann. Phys. u. Chem.' clviii. 375–386.
W. von Bezold .	Ueber die Vergleichung von Pigmentfarben mit Spectralfarben. (Read Jan. 8.)	'Sitzungsb. Akad. München,' vi. 30–34; 'Ann. Phys. u. Chem.' clviii. 165–169.

PHYSICAL RELATIONS, 1876, 1877.

W. von Bezold	Eine neue Methode der Farbenmischung. (Read March 4.)	'Sitzungsb. Akad. München,' vi. 106–112; 'Ann. Phys. u. Chem. clviii. 606–612.
E. Becquerel	Sur l'observation de la partie infra-rouge du spectre solaire, au moyen des effets de phosphorescence. (Read July 24.)	'C. R.' lxxxiii. 249–255; 'J. Chem. Soc.' 1876, ii. 587 (Abs.); 'Beiblätter,' i. 55–57 (Abs.)
H. Trannin	Mesures photométriques dans les différentes régions du spectre.	'J. de Phys.' v. 297–304; 'Beiblätter,' i. 106–108 (Abs.)
Aymonnet	Nouvelle méthode pour étudier les spectres calorifiques. (Read Dec. 4.)	'C. R.' lxxxiii. 1102–1104; 'Beiblätter,' i. 112–113.

1877.

E. Becquerel	Sur l'observation de la partie infra-rouge du spectre solaire, au moyen des effets de phosphorescence.	'Ann. Chim. et. Phys.' [5] x. 5–13.
K. W. Zenger	Ueber eine neue spectrometrische Methode. (Read Jan. 12.)	'Sitzungst. Prag. Ges.' 1877, 20–40; 'Beiblätter,' iii. 187–188 (Abs.)
P. Desains	Recherches sur les spectres calorifiques (suite). (Read Feb. 12.)	'C. R.' lxxxiv. 285–286; 'Phil. Mag.' [5] iii. 318–319; 'Beiblätter,' i. 238 (Abs.)
A. S. Herschel	Visibility of the Ultra-violet Rays of the Spectrum. (April 26.)	'Nature,' xvi. 22–23.
J. Hopkinson	Refractive Indices of Glass. (Recd. May 25. Read June 14.)	'Proc. Roy. Soc.' xxvi. 290–297; 'Beiblätter,' i. 680–681 (Abs.)
Gouy	Recherches photométriques sur les flammes colorées. (Read July 9.)	'C. R.' lxxxv. 70–72; 'J. Chem. Soc.' 1877, ii. 817 (Abs.); 'Phil. Mag.' [5] iv. 156–158; 'Beiblätter,' i. 472–473 (Abs.)
,,	Sur les caractères des flammes chargées de poussière saline. (Read Aug. 20.)	'C. R.' lxxxv. 439–442; 'J. Chem. Soc.' 1877, ii. 817 (Abs.)
Lord Rayleigh	On the Lower Limit of the Prismatic Spectrum, with especial reference to some Observations of Sir John Herschel.	'Phil. Mag.' [5] iv. 348–353; 'Beiblätter,' i. 682–683 (Abs.)
G. D. Liveing	Note on the Spectra of Calcium Fluoride. (Read Dec. 3.)	'Proc. Phil. Soc. Camb.' iii. 96–98; 'Beiblätter,' iv. 611–612 (Abs.)
E. Sarasin	Indices de réfraction ordinaire et extraordinaire du quartz, pour les rayons de différentes longueurs d'onde jusqu'à l'extrême ultra-violet.	'Arch. de Genève,' [2] lxi. 109–119; 'C. R.' lxxxv. 1230–1232 (Abs.); 'Beiblätter,' ii. 77–78 (Abs.)

PHYSICAL RELATIONS, 1878, 1879.

1878.

C. S. Hastings .	On the Influence of Temperature on the Optical Constants of Glass. (Jan. 1878.)	'Am. J.' [3] xv. 269–275; 'Beiblätter,' ii. 338–339 (Abs.)
A Arzruni . .	Ueber den Einfluss der Temperatur auf die Brechungsexponenten der natürlichen Sulfate des Baryum, Strontium und Blei.	'Zeitschr. f. Kryst. u. Mineral.' i. 165–192; 'Jahrb. f. Mineral.' 1877, 526–527 (Abs.); 'J. Chem. Soc.' xxxiv. 189–190 (Abs.)
Mascart . . .	Sur la réfraction des gaz et des vapeurs. (Read Feb. 4.)	'C. R.' lxxxvi. 321–323; 'J. Chem. Soc.' xxxiv. 359–360 (Abs.)
A. Hurion . .	Recherches sur la dispersion anomale.	'Ann. de l'Ecole Norm.' [2] vi. 367–412; 'Beiblätter,' ii. 79–86 (Abs.)
B. Hasselberg .	Zur Reduction der Kirchhoff'schen Spectralbeobachtungen auf Wellenlängen. (Read March 4.)	'Bull. de l'Acad. S. Petersb.' xxv. 131–146; 'Beiblätter,' iii. 79–80 (Abs.)
Gouy . . .	Sur la transparence des flammes colorées. (Read April 8.)	'C. R.' lxxxvi. 878–880; 'Beiblätter,' ii. 340–342 (Abs.); 'J. Chem. Soc.' xxxiv. 629–631 (Abs.)
H. Dufet . . .	Sur la variation des indices de réfraction dans les mélanges des sels isomorphes. (Read April 8.)	'C. R.' lxxxvi. 881–884.
Gouy . . .	Sur la transparence des flammes colorées pour leurs propres radiations. (Read April 29.)	'C. R.' lxxxvi. 1078–1080; 'Beiblätter,' ii. 411–412 (Abs.)
G. G. Stokes . .	On an Easy and at the same time Accurate Method of Determining the Ratio of the Dispersions of Glasses intended for Objectives. (Recd. June 18. Read June 20.)	'Proc. Roy. Soc.' xxvii. 485–494; 'Beiblätter,' iii. 185–187 (Abs.)
A. Crova . . .	Étude spectrométrique de quelques sources lumineuses. (Read Aug. 19.)	'C. R.' lxxxvii. 322–325; 'Phil. Mag.' [5] vi. 314–316; 'Beiblätter,' ii. 655–657 (Abs.)
Aymonnet and Maquenne.	Des minima produits, dans un spectre calorifique, par l'appareil réfringent et la lampe qui servent à la formation de ce spectre. (Read Sept. 30.)	'C. R.' lxxxvii. 494–497.
A. Crova . . .	Sur la mesure spectrométrique des hautes températures.	'C. R.' lxxxvii. 979–981; 'J. Chem. Soc.' xxxvi. 293 (Abs.); 'Beiblätter,' iii. 276–277 (Abs.)

1879.

C. S. Peirce . .	Note on the Progress of Experiments for comparing a Wave-length with a Metre.	'Am. J.' [3] xviii. 51; 'Beiblätter,' iii. 711 (Abs.)

PHYSICAL RELATIONS, 1879.

W. Crookes . .	De la lumière verte et phosphorescente du choc moléculaire. (Read Feb. 10.)	'C. R.' lxxxviii. 283-284.
G. W. A. Kahlbaum	Ueber einige Methylester aus der Propionsäure- und Buttersäuregruppe. (Recd. Feb. 27.)	'Ber.' xii. 343–344; 'J. Chem. Soc.' xxxvi. 521 (Abs.)
E. Wiedemann .	Ueber das Leuchten der Gase durch electrische Entladungen. Nachtrag zu der Arbeit über die Natur der Spectra. (Jan. 1879.)	'Ann. Phys. u. Chem.' N.F. vi. 298–302; 'Phil. Mag.' [5] vii. 248–251.
O. N. Rood . .	Analyse quantitative de la lumière blanche.	'Les Mondes,' xlviii. 610–611.
J. L. Soret . .	Sur la transparence des milieux de l'œil pour les rayons ultra-violets. (Read May 19.)	'C. R.' lxxxviii. 1012–1015; 'Beiblätter,' iii. 620 (Abs.)
G. D. Liveing . .	On the Dispersion of a Solution of Mercuric Iodide. (Read May 19.)	'Proc. Phil. Soc. Camb.' iii. 258–260; 'Beiblätter,' iv. 610–611 (Abs.)
Mouton . . .	Sur la détermination des longueurs d'onde calorifique. (Read May 26.)	'C. R.' lxxxviii. 1078–1082; 'Beiblätter,' iii. 616–618 (Abs.)
C. S. Peirce . .	On the Ghosts in Rutherfurd's Diffraction-Spectra. Comparison of Wave-lengths with the Metre. (U.S. Acad.)	'Am. J. Math.' ii. 330–347; 'Nature,' xx. 99 (Abs.); 'Beiblätter,' v. 48–50 (Abs.)
A. Crova . . .	Mesure spectrométrique des hautes températures.	'J. de Phys.' viii. 196–198.
W. de W. Abney .	On the Production of Coloured Spectra by Light. (Recd. June 9. Read June 19.)	'Proc. Roy. Soc.' xxix. 190; 'Chem. News,' xxxix. 282; 'Beiblätter,' iv. 285 (Abs.)
A Cornu . . .	Déterminations des longueurs d'onde des radiations très réfrangibles du magnésium, du cadmium, du zinc et de l'aluminium.	'Arch. de Genève' [3] ii. 119–126; 'Beiblätter,' iv. 34–35 (Abs.)
A, Baudrimont .	Évaporation de l'eau sous l'influence de la radiation solaire ayant traversé des verres colorés. (Read July 7.)	'C. R.' lxxxix. 41–43.
Thollon . . .	Minimum de dispersion des prismes; achromatisme de deux lentilles de mêmes substances. (Read July 14.)	'C. R.' lxxxix. 93-96; 'Beiblätter,' iv. 32–34 (Abs.)
W. Jacques . .	Vertheilung der Wärme in den Spectren verschiedener Wärmequellen (Inaug. Dissert. Johns Hopkins Univ. 1879).	'Beiblätter,' iii. 865–868 (Abs.)
P. Desains . .	Recherches sur la réfraction de la chaleur obscure. (Read July 28.)	'C. R.' lxxxix. 189–190; 'J. Chem. Soc.' xxxvi. 864 (Abs.); 'Beiblätter,' iii. 869–870 (Abs.)
Mouton . . .	Spectre calorifique normal du Soleil et de la lampe à platine incandescent (Bourbouze). (Read Aug. 4.)	'C. R.' lxxxix. 295–298; 'Beiblätter,' iii. 868–869 (Abs.)

Physical Relations, 1879, 1880.

Thenard . . .	Remarques. (Read Aug. 4) . .	'C. R.' lxxxix. 298–299; 'Beiblätter,' iv. 39 (Abs.)
E. L. Nichols . .	On the Character and Intensity of the Rays emitted by Glowing Platinum. (May 28.)	'Am. J.' [3] xviii. 446–468.
" . .	Upon an Optical Method for the Measurement of High Temperatures. (July 1.)	'Am. J.' [3] xix. 42–49.
Gouy . . .	Recherches photométriques sur les flammes colorées.	'Ann. Chim. et Phys.' [5] xviii. 5–101; 'Beiblätter,' iv. 376–378 (Abs.)
Sir J. Conroy . .	The Distribution of Heat in the Visible Spectrum. (Read June 28.)	'Proc. Phys. Soc.' iii. 106–112; 'Phil. Mag.' [5] viii. 203–209; 'Beiblätter,' iv. 44 (Abs.)
Van Monckhoven .	Ueber die Vertheilung der chemischen Lichtintensität im Sonnenspectrum. ('Photog. Mittheilungen,' xvi. 145–146.)	'Beiblätter,' iv. 49 (Abs.)
A. Schuster . .	On Harmonic Ratios in the Spectra of Gases.	'Nature,' xx. 533; 'Beiblätter,' iv. 37–38 (Abs.)
De Klercker . .	Sur le spectre anormal de la lumière. (Read Nov. 3.)	'C. R.' lxxxix. 734–736; 'Phil. Mag.' [5] viii. 571–572; 'Beiblätter,' iv. 273–274 (Abs.)
H. W. Vogel . .	Chemische Intensität des Magnesium- und electrischen Lichtes. ('Photog. Mittheilungen,' xvi. 187–188.)	'Beiblätter,' iv. 280 (Abs.)
Mouton . . .	Sur les lois de la dispersion des rayons calorifiques obscurs et la mesure de leurs longueurs d'onde.	'Ann. Chim. et Phys.' [5] xviii. 145–189.
G. Sieben . .	Untersuchungen über die anomale Dispersion des Lichtes. (Jan. 1879.)	'Ann. Phys. u. Chem. N.F. viii. 137–157.
L. Bleekrode . .	Experimentaluntersuchung zur Bestimmung der Brechungsexponenten verflüssigter Gase. (July 1879.)	'Ann. Phys. u. Chem.' N.F. viii. 400–407.
Gouy . . .	Sur la mesure de l'intensité des raies d'absorption et des raies obscures du spectre solaire. (Read Dec. 15.)	'C. R.' lxxxix. 1033–1034; 'Beiblätter,' iv. 369–370 (Abs.)
C. S. Pierce . .	Mutual Attraction of Spectral Lines. (Nov. 14.)	'Nature,' xxi. 108; 'Beiblätter,' iv. 278 (Abs.)

1880.

A. Crova . . .	Mesure spectrométrique des hautes températures. (Read Feb. 9.)	'C. R.' xc. 252–254; 'Beiblätter,' iv. 362–363 (Abs.)
W. H. Pickering .	Photometric Researches. (Feb 11.)	'Proc. Am. Acad.' xv. 236–250; 'Beiblätter,' iv. 728–729 (Abs.)

PHYSICAL RELATIONS, 1880.

A. Kundt . . .	Ueber anomale Dispersion im glühenden Natriumdampf. (March 1880.)	'Ann. Phys. u. Chem.' N.F. x. 321–325; 'Phil. Mag.' [5] x. 53–57.
A. Crova . . .	Étude des radiations émises par les corps incandescents. Mesure optique des hautes températures.	'Ann. Chim. et Phys.' [5] xix. 472–550; 'Beiblätter,' v. 117–118 (Abs.)
J. V. Janowsky .	Die Aenderung des Moleculargewichtes und das Molecularrefractionsvermögen. (Read Mar. 18 and June 3.)	'Sitzungsb. Wien. Akad.' lxxxi. II. 539–553; lxxxii. II. 147–158.
J. Macé and W. Nicati.	Étude de la distribution de la lumière dans le spectre. (Read May 31.)	'C. R.' xc. 1275–1277; 'Beiblätter,' iv. 619 (Abs.)
J. G. Lohse . .	On the Refractive and Dispersive Powers of various Samples of Glass. (Read June 11.)	'Monthly Not. Astr. Soc.' xl. 563–564; 'Beiblätter,' iv. 891 (Abs.)
P. Desains and J. Curie.	Recherches sur la détermination des longueurs d'onde des rayons calorifiques à basse température. (Read June 28.)	'C. R.' xc. 1506–1509; 'Beiblätter,' iv. 892-893 (Abs.)
J. Janssen . .	Note sur les transformations successives de l'image photographique par la prolongation de l'action lumineuse. (Read July 26.)	'C. R.' xci. 199.
H. Dufet . .	Sur les propriétés optiques des mélanges de sels isomorphes. (Read Aug. 2.)	'C. R.' xci. 286–289; 'J. Chem. Soc.' xl. 2 (Abs.)
Damien . . .	Indices de réfraction des dissolutions aqueuses d'acide acétique et d'hyposulfite de soude. (Read Aug. 9.)	'C. R.' xci. 323–325; 'Beiblätter,' v. 41–42 (Abs.)
Gouy . . .	Mesure de l'intensité de quelques raies obscures du spectre solaire. (Read Aug. 16.)	'C. R.' xci. 383; 'J. Chem. Soc.' xl. 333 (Abs.); 'Beiblätter,' v. 46 (Abs.)
P. Thenard . .	Notices spectroscopiques . .	'C. R.' xci. 387; 'Beiblätter,' v. 44 (Abs.)
C. Fiévez . .	Recherches sur l'intensité relative des raies spectrales de l'hydrogène et de l'azote en rapport avec les constitutions des nébuleuses. (Read Feb. 7.)	'Bull. Soc. de l'Acad. Belgique' [2] xlix. 107–113; 'Ann. Chim. et Phys.' [5] xx. 179–185; 'J. Chem. Soc.' xl. 69–70 (Abs.)
L. Lorenz . .	Ueber die Refractionsconstante .	'Ann. Phys. u. Chem.' N.F. xi. 70–103.
K. Prytz . . .	Experimentelle Untersuchungen über die Refractionsconstante.	'K. Dän Ges. d. Wiss. 1880, vi. 3–22; 'Ann. Phys. u. Chem.' N.F. xi. 104–120.
J. H. Gladstone .	On the Refraction Equivalents of the Diamond, and the Carbon Compounds.	'Chem. News,' xlii. 175; 'J. Chem. Soc.' xl. 333 (Abs.); 'Beiblätter,' v. 43 (Abs.)

PHYSICAL RELATIONS, 1880, 1881.

O. Hesse	Untersuchungen über das Dispersionsgesetz. (Aug. 1880.)	'Ann. Phys. u. Chem.' N.F. xi. 871–908.
J. Macé and W. Nicati	Étude de la distribution de la lumière dans le spectre solaire. (Read Oct. 11.)	'C. R.' xci. 623–625; 'Beiblätter,' v. 301–302 (Abs.)
H. C. Vogel	Resultate spectralphotometrischer Untersuchungen. (Read Oct. 21.)	'Monatsb. Berl. Akad.' 1880, 801–811; 'Beiblätter,' v. 286–288 (Abs.)
J. L. Soret	Absorption des rayons ultra-violets.	'Arch. de Genève' [3] iv. 377–380.
A. Rilliet	Remarques	'Arch. de Genève' [3] iv. 380–381.
J. V. Janowsky	Ueber optische Constanten. (Recd. Dec. 6. Read Dec. 13.)	'Ber.' xiii. 2272–2277.
J. Macé and W. Nicati.	De la distribution de la lumière dans le spectre solaire (spectre des daltoniens). (Read Dec. 27.)	'C. R.' xci. 1078–1080; 'Beiblätter,' v. 301–302 (Abs.)

1881.

L. Thollon	Minimum du pouvoir de résolution d'un prisme. (Read Jan. 17.)	'C. R.' xcii. 128–130.
A. Schuster	On Harmonic Ratios in the Spectra of Gases. (Recd. Jan. 10. Read Jan. 27.)	'Proc. Roy. Soc.' xxxi. 337–347; 'Beiblätter,' v. 435–438 (Abs.)
Hurion	Application des franges de Talbot à la détermination des indices de réfraction des liquides. (Read Feb. 28.)	'C. R.' xcii. 452–453.
E. Ketteler	Experimentaluntersuchung über den Zusammenhang zwischen Refraction und Absorption des Lichtes. (Jan. 1881.)	'Ann. Phys. u. Chem. N.F. xii. 481–519.
T. C. Medenhall	On the Determination of the Coefficient of Expansion of a Diffraction Grating by means of the Spectrum.	'Am. J.' [3] xxi. 230–232.
J. H. Long	On the Indices of Refraction of certain Compound Ethers. (Feb. 1881.)	'Am. J.' [3] xxi. 279–286.
S. P. Langley	Sur la distribution de l'énergie dans le spectre solaire normal. (Read March 21.)	'C. R.' xcii. 701–703; 'Beiblätter,' v. 510 (Abs.)
W. E. Ayrton and J. Perry.	Measuring the Index of Refraction of Ebonite.	'Nature,' xxiii. 519.
V. v. Lang	Ueber die Dispersion des Aragonits nach Arbiträrer Richtung. (Read Mar. 31.)	'Sitzungsb. Wien. Akad.' lxxxiii. II. 671–676; 'Wien. Anz.' 1881, 84; (Abs.)
J. Violle	Intensités lumineuses des radiations émises par le platine incandescent. (Read April 4.)	'C. R.' xcii. 866–868, 1204–1206; 'Beiblätter,' v. 503–504 (Abs.)

PHYSICAL RELATIONS, 1881—FLUORESCENCE, 1871, 1872.

A. Crova . . .	Étude des aberrations des prismes et de leur influence sur les observations spectroscopiques.	'Ann. Chim. et Phys.' [5] xxii. 513–543.
J. W. Brühl . .	Die optischen Untersuchungen des Herrn Janowsky. (April 1881. Read June 13.)	'Ber.' xiv. 1306–1310.
W. Crookes .	On Discontinuous Phosphorescent Spectra in High Vacua.	'Proc. Roy. Soc.' xxxii. 206–213; 'Nature,' xxiv. 89–91; 'Chem. News,' xliii. 237–239; 'Ber.' xiv. 1696–1697(Abs.)
W. de W. Abney and R. Festing.	On the Transmission of Radiation of Low Refragibility through Ebonite. (Read April 9.)	'Proc. Phys. Soc.' iv. 256–259; 'Phil. Mag.' [5] xi. 466–469; 'Chem. News,' xliii. 175–176 (Abs.); 'Beiblätter,' v. 506–507 (Abs.)
K. Vierordt . .	Die Photometrie der Fraunhofer'-schen Linien. (April 1881.)	'Ann. Phys. u. Chem.' N.F. xiii. 338–346.
F. Lippich . . .	Ueber die Lichtstärke der Spectralapparate.	'Centr. Zeit. f. Opt. u. Mech.' ii. 49–50, 61–62; 'Beiblätter,' v. 585–588 (Abs.)

FLUORESCENCE.

1871.

E. Lommel . .	Ueber Fluorescenz (Read Feb. 20.)	'Sitzungsb. phys.-med. Soc. Erlangen,' 1871, 39–60; 'Ann. Phys. u. Chem.' cxliii. 26–51; 'Ann. Chim. et Phys.' [4] xxvi. 283–285 (Abs.)
H. Morton . .	Observations on the Colour of Fluorescent Solutions.	'Chem. News,' xxiv. 77; 'J. Chem. Soc.' [2] ix. 992–993 (Abs.)
" . .	Observations on the Colour of Fluorescent Solutions. (July 1871.)	'Am. J.' [3] ii. 198–199, 355–357; 'J. Chem. Soc.' [2] ix. 992–993 (Abs.), [2] x. 27–28 (Abs.)

1872.

E. Hagenbach . .	Versuche über Fluorescenz. (Jan. 1872.)	'Ann. Phys. u. Chem.' cxlvi. 65–89, 232–257, 375–405 508–538; 'J. Chem. Soc.' [2] x. 1058–1061 (Abs.); 'Phil. Mag.' [4] xlv. 57–64 (Abs.); 'Chem. News,' xxvi. 173–174 (Abs.)
E. Becquerel . .	Analyse de la lumière émise par les composés d'uranium phosphorescents. (Read Aug. 5.)	'C. R.' lxxv. 296–303; 'J. Chem. Soc.' [2] xi. 25 (Abs.); 'Am J.' [3] iv. 486–487 (Abs.)

FLUORESCENCE, 1872–1877.

H. Morton . .	Fluorescent Relations of certain solid Hydrocarbons found in Coal-tar and Petroleum Distillates.	'Phil. Mag.' [4] xliv. 345–349; 'Ann. Phys. u. Chem.' cxlviii. 292–297; 'Chem. News,' xxvi. 199–201, 272–274; 'J. Chem. Soc.' [2] xi. 235 (Abs.)
E. Becquerel . .	Mémoire sur l'analyse de la lumière émise par les composés d'uranium phosphorescents.	'Ann. Chim. et Phys.' [4] xxvii. 539–579.

1873.

H. Morton . .	Fluorescent Relations of certain solid Hydrocarbons found in Petroleum Distillates.	'Phil. Mag.' xlvi. 89–102; 'J. Chem. Soc.' [2] xii. 14–15 (Abs.)

1874.

E. Hagenbach . .	Fernere Versuche über Fluorescenz.	'Ann. Phys. u. Chem.' Jubelband, 303–313.
H. Morton and H. C. Bolton.	Investigation of the Fluorescent and Absorption Spectra of the Uranium Salts.	'Chem. News,' xxviii. 47–50, 113–116, 164–167, 233–234, 244–246, 257–259, 268–270; 'J. Chem. Soc.' [2] xii. 12–13 (Abs.)
H. Morton . .	Fluorescent Relations of the Basic Salts of Uranic Oxide.	'Chem. News,' xxix. 17–18; 'J. Chem. Soc.' [2] xii. 642 (Abs.)
C. Horner . .	A Note on the Behaviour of certain Fluorescent Bodies in Castor Oil.	'Phil. Mag.' [4] xlviii. 165–166.
O. Lubarsch . .	Ueber Fluorescenz. (Sept. 1874) .	'Ann. Phys. u. Chem.' cliii. 420–440; 'J. Chem. Soc.' [2] xiii. 528 (Abs.)

1875.

H. Morton . .	Fluorescent Relations of Chrysene and Pyrene.	'Chem. News,' xxxi. 35–36, 45–47.
" . .	Fluorescenzverhältnisse gewisser Kohlenwasserstoffverbindungen in den Steinkohlen- und Petroleum-destillaten.	'Ann. Phys. u. Chem.' clv. 551–579.
H. C. Sorby . .	On the Connection between Fluorescence and Absorption.	'Monthly Mic. J.' xiii. 161–164.

1876.

E. Lommel . .	Ueber Fluorescenz. (July 1876) .	'Ann. Phys. u. Chem.' clix. 514–536; 'J. Chem. Soc.' 1877, i. 676; 'Am. J.' [3] xiii. 380 (Abs.)

1877.

E. Lommel . .	Ueber die Intensität des Fluorescenzlichts. (Nov. 6, 1876.)	'Ann. Phys. u. Chem.' clx. 75–96.
B. Brauner	Versuche über Fluorescenz . .	'Wien. Anz.' 1877, 178–180; 'Beiblätter,' ii. 152–153 (Abs.)

FLUORESCENCE, 1877–1879.

E. Hagenbach .	Das Aufleuchten, die Phosphorescenz und Fluorescenz des Flussspaths. (Naturforscherversammlung in München, 1877.)	'Ber.' x. 2232 (Abs.)
E. Lommel . .	Fluorescenz. (Naturforscherversammlung.)	'Ber.' x. 2232 (Abs.)
M. von Bezold and G. Engelhardt.	Ueber die Fluorescenz der lebenden Netzhaut. (Read July 7.)	'Sitzungsb. Akad. München,' vii. 226–233; 'Phil. Mag.' [5] iv. 397–400.
E. Lommel . .	Ueber Fluorescenz. (Read July 23, 1877.)	'Sitzungsb. der physik.-med. Soc. zu Erlangen,' 1877, 196–206; 'Ann. Phys. u. Chem.' N.F. iii. 113–125; 'J. Chem. Soc.' xxxiv. 358–359 (Abs.)

1878.

Favé . . .	Les vibrations de la matière et les ondes de l'éther dans la phosphorescence et la fluorescence. (Read Feb. 4.)	'C. R.' lxxxvi. 289–294.
A. Wüllner . .	Berichtigung zu einer Notiz des Hrn. Lommel betreffend die Theorie der Fluorescenz. (Mar. 8, 1877.)	'Ann. Phys. u. Chem.' Ergänzungsb. 1878, viii. 474–478.
E. Lommel . .	Ueber zwei neue fluorescirende Substanzen. (Read July 29.)	'Sitzungsb. d. phys.-med. Soc. zu Erlangen,' 1878, 210–212; 'Ann. Phys. u. Chem.' N.F. vi. 115–118.

1879.

O. Lubarsch . .	Ueber Fluorescenz. (Oct. 1878.) .	'Ann. Phys. u. Chem.' N.F. vi. 248–267.
J. L. Soret . .	Sur la fluorescence des sels des métaux terreux. (Read May 26.)	'C. R.' lxxxviii. 1077–1078; 'J. Chem. Soc.' xxxvi. 862 (Abs.); 'Beiblätter,' iii. 620 (Abs.)
S. Lamansky . .	Sur la loi de Stokes. (Read June 9)	'C. R.' lxxxviii. 1192–1194; 'J. Chem. Soc.' xxxvi. 862 (Abs.); 'Beiblätter,' iii. 619 (Abs.)
E. Becquerel . .	Observations relatives à une note de M. Lamansky ayant pour titre 'Sur la loi de Stokes.' (Read June 16.)	'C. R.' lxxxviii. 1237–1239; 'Beiblätter,' iii. 619 (Abs.); 'J. Chem. Soc.' xxxvi. 862 (Abs.)
E. Lommel . .	Ueber das Stokes'sche Gesetz . .	'Ann. Phys. u. Chem.' N.F. viii. 244–253.
S. Lamansky . .	Sur la loi de Stokes. Réponse à M. E. Becquerel. (Read June 30.)	'C. R.' lxxxviii. 1351–1352; 'Beiblätter,' iii. 619 (Abs.)
E. Hagenbach . .	Das Stokes'sche Gesetz. (July 1879)	'Ann. Phys. u. Chem.' N.F. viii. 369–400.
S. Lamansky . .	Ueber das Stokes'sche Gesetz. (Aug. 1879.)	'Ann. Phys. u. Chem.' N.F. viii. 624–628.

FLUORESCENCE, 1880—ASTRONOMICAL APPLICATIONS, 1870, 1871.

1880.

O. Lubarsch	Das Stokes'sche Gesetz. (Jan. 1880)	'Ann. Phys. u. Chem.' N.F. ix. 665–671.
E. Lommel	Ueber Fluorescenz	'Ann. Phys. u. Chem.' N.F. x. 449–472, 631–654.
C. Liebermann	Ueber die Fluorescenz in der Anthracenreihe. (Read April 26.)	'Ber.' xiii. 913–916.
O. Lubarsch	Neue Experimentaluntersuchungen über Fluorescenz. (May 1880.)	'Ann. Phys. u. Chem.' N.F. xi. 46–69; 'J. Chem. Soc.' xl. 70 (Abs.)
S. Lamansky	Ueber Fluorescenz. (July 1880)	'Ann. Phys. u. Chem.' N.F. xi. 908–912; 'J. Chem. Soc.' xl. 214–215 (Abs.)

ASTRONOMICAL APPLICATIONS.

1870.

C. A. Young	Spectroscopic Observations of the Sun (communicated by J. N. Lockyer).	'Nature,' iii. 34.
S. J. Perry	The Chromosphere	„ iii. 67.
C. A. Young	Spectroscopic Notes. (Oct. 3.)	'J. Franklin Inst.' lx. 331–340; 'Nature,' iii. 110–113.
F. Zöllner	Ueber die Periodicität und heliographische Verbreitung der Sonnenflecken. (Read Dec. 12.)	'Ber. d. K. Sächs. Ges. d. Wiss.' xxii. 338–350; 'Ann. Phys. u. Chem.' cxlii. 524–539.
L. Respighi	Sulle protuberanze solari	'Bull. Met. dell' osserv. del Coll. Rom.' ix. 89–91; 'Am. J.' [3] i. 283–287.

1871.

W. Zenker	Ueber die Beobachtung der Sonnenprotuberanzen im monochromatischen Lichte.	'Ann. Phys. u. Chem.' cxlii. 172–176.
J. N. Lockyer	The Mediterranean Eclipse, 1870	'Nature,' iii. 221–224; 321–322; 'Am. J.' [3] i. 224–230.
Lord Lindsay	Report of Observations, &c. of the Total Eclipse of the Sun taken at 'Le Maria Luisa' Vineyard, Cadiz, Dec. 21–22, 1870. (Read Jan. 13.)	'Monthly Not. Astr. Soc.' xxxi. 49–60.
R. Abbay	On the Solar Eclipse of Dec. 22, 1870, observed at Xeres in Spain. (Read Jan. 13.)	'Monthly Not. Astr. Soc.' xxxi. 60–62.
S. J. Perry	Solar Eclipse, Dec. 22, 1870, observed at San Antonio, near Puerto de Sta. Maria. (Read Jan. 13.)	'Monthly Not. Astr. Soc.' xxxi. 62–63.
C. A. Young	Note on Chromosphere Lines	'Nature,' iii. 266–267.
W. A. Norton	On the Corona seen in Total Eclipses of the Sun.	'Am. J.' [3] i. 5–15; 'Phil. Mag.' [4] xli. 225–236.

Astronomical Applications, 1871.

S. J. Perry . .	The Solar Eclipse. (Dec. 22, 1870. Read Mar. 10.)	'Monthly Not. Astr. Soc.' xxxi. 149–151.
A. Secchi . . .	Nouveaux résultats d'observations, concernant la constitution physique du Soleil. (Mar. 20. Read Mar. 27.)	'C. R.' lxxii. 362–366.
C. A. Young . .	On the Solar Corona. (March 23.)	'Am. J.' [3] i. 311–373.
H. R. Procter . .	The Spectra of the Aurora and Corona. (Mar. 28.)	'Nature,' iii. 468.
B. E. Hammond .	The Comparative Aggregate Strength of the Light from the Red Hydrogen-Stratum, and of that from the rest of the Chromosphere. (April 11.)	„ iii. 487.
C. Piazzi Smyth .	Spectra of Aurora, Corona, and Zodiacal Light. (April 14.)	„ iii. 509–510.
W. Huggins . .	Note on the Spectrum of Uranus and the Spectrum of Comet I. 1871. (Recd. May 10. Read May 25.)	'Proc. Roy. Soc.' xix. 488–491; 'Phil. Mag.' [4] xlii. 223–226; 'Nature,' iv. 88; 'Chem. News,' xxiii. 265; 'Am. J.' [3] ii. 138 (Abs.)
C. A. Young . .	Note on the Spectrum of the Corona. (May 10.)	'Am. J.' [3] ii. 53–55; 'Chem. News,' xxiv. 198–199.
A. Secchi . .	Sur les relations qui existent, dans le Soleil, entre les facules, les protubérances et la couronne. (June 13. Read June 26.)	'C. R.' lxxii. 829–832.
F. Zöllner . .	Ueber die spectroskopische Beobachtung der Rotation der Sonne und ein neues Reversionsspectroskop. (Read July 1.)	'Ber. d. K. sächs. Ges. d. Wiss.' xxiii. 300–306; 'Ann. Phys. u. Chem.' cxliv. 449–456; 'Phil. Mag.' [4] xliii. 47–52; 'Ann. Chim. et Phys.' [4] xxvi. 274–275 (Abs.); 'Am. J.' [3] iii. 299 (Abs.)
A. Secchi . .	Sur les relations qui existent, dans le Soleil, entre les facules, les protubérances et la couronne. (July 17. Read July 24).	'C. R.' lxxiii. 242–246.
W. A. Norton . .	On the Physical Constitution of the Sun. (June 1871.)	'Am. J.' [3] i. 395–407; 'Phil. Mag.' [4] xlii. 55–67.
J. Janssen . .	Études sur les raies telluriques du spectre solaire.	'Ann. Chim. et Phys.' xxiii. 274–299.
„ . .	Sur la constitution du soleil. (Read Aug 14.)	'C. R.' lxxiii. 432–436.
A. Cornu . .	Réponse à une note de M. Janssen. (Read Aug. 28.)	„ lxxiii. 545.
A. Secchi . .	Sur les relations qui existent, dans le Soleil, entre les protubérances et les autres parties remarquables. (Aug. 26. Read Sept. 4.)	„ lxxiii. 593–599.

ASTRONOMICAL APPLICATIONS, 1871, 1872.

G. Rayet . .	Mémoire sur les raies brillantes du spectre de l'atmosphère solaire et sur la constitution physique du Soleil.	'Ann. Chim. et Phys.' [4] xxiv. 5–80.
D. Kirkwood .	On the Testimony of the Spectroscope to the truth of the Nebular Hypothesis.	'Am. J.' [3] ii. 155–156; 'Phil. Mag.' [4] xlii. 399–400.
C. A. Young . .	Preliminary Catalogue of the bright lines in the Spectrum of the Chromosphere. (Sept. 13.)	'Am. J.' [3] ii. 332–335; 'Phil. Mag.' [4] xlii. 377–380; 'Nature,' v. 312–313.
" . .	An Explosion (?) on the Sun. (Sept. 13, 1871.) 'Boston Journ. Chem.'	'Am. J.' [3] ii. 468–470; 'Nature,' iv. 488–489; 'Phil. Mag.' [4] xliii. 76–79.
J. Janssen . .	Remarques sur une dernière Note de M. Cornu. (Read Sept. 25.)	'C. R.' lxxiii. 793–794.
A. Secchi . .	Sur les divers aspects des protubérances et des autres parties remarquables, à la surface du Soleil. Classification des phénomènes. (Sept. 21. Read Oct. 2.)	" lxxiii. 826–836.
" . .	Ditto. (Oct. 10. Read Oct. 23) .	" lxxiii. 979–983.
Faye . . .	Sur la mesure spectroscopique de la rotation du Soleil au moyen du spectroscope à réversion du Dr. Zöllner. (Read Nov. 13.)	" lxxiii. 1122–1123.
" . . .	Sur la loi de rotation du Soleil; réponse à une réclamation du P. Secchi et à un mémoire du Dr. Zöllner. (Read Nov. 13.)	" lxxiii. 1123–1131.
A. Secchi . .	Sur un nouveau moyen de mesurer les hauteurs des protubérances solaires. (Nov. 21. Read Dec. 4.)	" lxxiii. 1297–1301.
W. Huggins . .	Note on the Spectrum of Encke's Comet. (Recd. Nov. 16. Read Nov. 23.)	'Proc. Roy. Soc.' xx. 45–47; 'Phil. Mag.' [4] xliii. 380–382.
C. Piazzi Smyth .	Note on a possible Ultra-Solar Spectroscopic Phenomenon.	'Proc. Roy. Soc.' xx. 136.

1872.

J. Janssen . .	Lettre de M. Janssen sur les conséquences principales qu'il peut, dès aujourd'hui, tirer de ses observations sur l'éclipse de décembre dernier. (Dec. 19, 1871. Read Jan. 15, 1872.)	'C. R.' lxxiv. 175–176; 'J. Chem. Soc.' [2] x. 590 (Abs.)
" . .	Eclipse of the Sun, Dec. 12, 1871 .	'Am. J.' [3] iii. 226.
" . .	Note on the Eclipse of the Sun (Dec. 1871) as observed at Sholoor. (Recd. Jan. 15. Read Feb. 1.)	'Proc. Roy. Soc.' xx. 138–139.
J. N. Lockyer . .	The Solar Eclipse. (Dec. 19, 1871)	'Nature,' v. 217–219; 'Am. J.' [3] iii. 226–230.

ASTRONOMICAL APPLICATIONS, 1872.

J. P. Maclear . .	The Solar Eclipse. (Jan. 6) . .	'Nature,' v. 219–221; 'Am. J.' [3] iii. 310–312.
J. Janssen . .	The Total Solar Eclipse of 12 Dec., 1871. (Dec. 19, 1871. Read Jan. 12.)	'Monthly Not. Astr. Soc.' xxxii. 69–70.
Col. Tennant . .	The Total Solar Eclipse of 12 Dec., 1871. (Dec. 12, 1871. Read Jan. 12.)	'Monthly Not. Astr. Soc.' xxxii. 70–72.
A. Secchi . .	Sur les protubérances solaires. (Read Jan. 22.)	'C. R.' lxxiv. 218–224; 'Monthly Not. Astr. Soc.' xxxii. 226–230 (Abs.)
C. A. Young . .	On the Results of the Eclipse Observations.	'Am. J.' [3] iii. 314–315
E. Liais . .	Sur l'analyse spectrale de la lumière zodiacale, et sur la couronne des éclipses. (Read Jan. 22.)	'C. R.' lxxiv. 262–264; 'Am. J.' [3] iii. 390–391.
Peslin . . .	Sur les raies du spectre solaire. (Read Jan. 29.)	'C. R.' lxxiv. 325–327.
P. Blaserna . .	Sur l'atmosphère solaire. (Read Feb. 5.)	„ lxxiv. 378, 379.
G. K. Winter . .	Observations on the Corona seen during the Eclipse of Dec. 11 and 12, 1871. (Jan. 27, 1872.)	'Phil. Mag.' [4] xliii. 191–194.
L. Respighi . .	The Solar Eclipse	'Nature,' v. 237–238; 'Am. J.' [3] iii. 312–314.
C. Abbe . . .	Observations on the Total Eclipse of the Sun of 1869. (Feb. 6, 1872.)	'Am. J.' [3] iii. 264–267.
L. Respighi . .	Sur l'analyse de la lumière zodiacale. (Read Feb. 19.)	'C. R.' lxxiv. 514–517.
A. Secchi . .	Sur quelques particularités de la constitution du Soleil. (Read April 22.)	„ lxxiv. 1087–1091.
„ . .	Résumé des observations des protubérances solaires du 1er janvier au 29 avril. (May 7. Read May 20.)	„ lxxiv. 1315–1320; 'Monthly Not. Astr. Soc.' xxxii. 318–320 (Abs.)
L. Respighi . .	Réponse à une Note précédente du P. Secchi sur quelques particularités de la constitution du Soleil. (Read May 27.)	'C. R.' lxxiv. 1387–1390.
W. Huggins . .	On the Spectrum of the Great Nebula in Orion, and on the Motions of some Stars towards or from the Earth. (Recd. May 2. Read June 13.)	'Proc. Roy. Soc.' xx. 379–394; 'Phil. Mag.' [4] xlv. 133–147; 'Nature,' vi. 231–235; 'Am. J.' [3] v. 75–78; 'Monthly Not. Astr. Soc.' xxxii. 359–362.
C. Piazzi Smyth .	Spectroscopic Observations of the Zodiacal Light in April 1872, at the Royal Observatory, Palermo. (Read June 14.)	'Monthly Not. Astr. Soc.' xxxii. 277–288; 'Am. J.' [3] iv. 245–246 (Abs.)
A. Secchi . .	Réponse aux observations présentées par M. Respighi sur quelques particularités de la constitution du Soleil. (Read June 17.)	'C. R.' lxxiv. 1501–1507.

ASTRONOMICAL APPLICATIONS, 1872.

J. H. Leach . .	Spectroscopic Notes . . .	'Journ. Franklin Inst.' lxiii. 418–419; 'Nature,' vi. 125–126.
Tacchini . .	Sur une apparition singulière de magnésium dans le chromosphère du Soleil. (Read July 1.)	'C. R.' lxxv. 23–25; 'Phil. Mag.' [4] xliv. 159–160.
H. C. Vogel . .	Ueber die Absorption der chemisch-wirksamen Strahlen in der Atmosphäre der Sonne. (Read July 1.)	'Ber. d. K. Sächs. Ges. d. Wiss.' xxiv. 135–141; 'Ann. Phys. u. Chem.' cxlviii. 161–168; 'Phil. Mag.' [4] xlv. 345–350; 'J. Chem. Soc.' [2] xi. 712 (Abs.)
A. Schuster . .	Note on the above	'Phil. Mag.' [4] xlv. 350.
L. Respighi . .	Réponse aux critiques présentées par le P. Secchi, à propos des observations faites sur quelques particularités de la constitution du Soleil. (Read July 15.)	'C. R.' lxxv. 134–138 (Abs.)
P. Tacchini . .	Forms of Solar Protuberances .	'Nature,' vi. 293–294.
A. Secchi . .	Sur l'éruption solaire observée le 7 juillet, et sur les phénomènes qui l'ont accompagnée. (July 24. Read Aug. 5.)	'C. R.' lxxv. 314–322.
J. Herschel . .	The Solar Spectrum. (Aug. 25) .	'Nature,' vi. 454–455.
Tacchini . . .	Suite des observations relatives à la présence de magnésium dans la chromosphère du Soleil. (July 30. Read Aug. 12.)	'C.R.' lxxv. 430–431; 'Phil. Mag.' [4] xliv. 479–480.
E. Vicaire . .	Sur la constitution physique du Soleil. (Read Aug. 26.)	'C. R.' lxxv. 527–531.
A. Secchi . .	Observations des variations des diamètres solaires; observations des protubérances et de la chromosphère; observation des étoiles filantes; aurore boréale observée à Rome le 10 août, à 10 heures du matin. (Aug. 27. Read Sept. 9.)	,, lxxv. 606–613.
C. A. Young . .	Letter to the Superintendent of the U.S. Coast Survey, containing a Catalogue of Bright Lines in the Spectrum of the Solar Atmosphere, observed at Sherman, Wyoming Territory, U.S.A., during July and August 1872.	'Am. J.' [3] iv. 356–362; 'Nature,' vii. 17–20.
A. Secchi . .	Sur les diverses circonstances de l'apparition d'un bolide aux environs de Rome et sur les spectres stellaires. (Sept. 7. Read Sept. 16.)	'C. R.' lxxv. 655–659.
,, . .	Recherches spectroscopiques solaires, communiquées par le P. Secchi. (Read Sept. 30.)	,, lxxv. 749–750.
,, . .	Italian Spectroscopy . . .	'Nature,' vi. 465–466.
J. F. Tennant .	Solar Spectroscopic Observations. (Oct. 4.)	,, vi. 492.

ASTRONOMICAL APPLICATIONS, 1872, 1873.

J. R. Capron . .	The Solar Spectrum. (Oct. 7.) .	'Nature,' vi. 492.
J. P. Maclear . .	Solar Spectroscope Observations. (Oct. 18.)	„ vi. 514.
C. A. Young . .	The Corona Line. (Oct. 10.). .	„ vii. 28.
„ . .	The Sherman Astronomical Expedition. (Nov. 25.)	„ vii. 107–109.
A. Secchi . .	Sur les taches et le diamètre solaires. (Nov. 22. Read Dec. 9.)	'C. R.' lxxv. 1581–1584.
J. N. Lockyer . .	Researches in Spectrum-Analysis in connection with the Spectrum of the Sun. No. I. (Recd. Nov. 6. Read Dec. 12.)	'Phil. Trans.' 1873, clxiii. 253–275; 'Proc. Roy. Soc.' xxi. 83–85 (Abs.); 'Phil. Mag.' [4] xiv. 147–148 (Abs.); 'J. Chem. Soc.' [2] xi. 994–995 (Abs.); 'Am. J.' [3] v. 236–237 (Abs.)
„ . .	Recherches expérimentales sur le spectre solaire. (Read Dec. 30.)	'C. R.' lxxv. 1816–1819; 'J. Chem. Soc.' [2] xi. 340 (Abs.)

1873.

J. N. Lockyer and G. M. Seabroke.	On a new Method of viewing the Chromosphere. (Recd. Nov. 6, 1872. Read Jan. 9, 1873.)	'Proc. Roy. Soc.' xxi. 105–107; 'Am. J.' [3] v. 319 (Abs.); 'Phil. Mag.' [4] xlv. 222–224; 'C. R.' lxxvi. 363–365.
W. Huggins . .	Note on the Wide-slit Method of Viewing the Solar Prominences (correction of Note in 'Proc. Roy. Soc.' xvii. 302). (Recd. Nov. 21, 1872. Read Jan. 23, 1873.)	'Proc. Roy. Soc.' xxi. 127–128.
J. R. Capron . .	The Spectrum of the Aurora and of the Zodiacal Light (List of Authorities on the Subject). (Nov. 9, 1872.)	'Nature,' vii. 182–186.
E. W. Pringle . .	Spectroscopic Observations. (Nov. 26, 1872.)	„ vii. 222.
Spörer	Notiz über eine ausgezeichnete Protuberanz. (Sept. 1872.)	'Ann. Phys. u. Chem.' cxlviii. 171–172.
A. Secchi . .	Sur les protubérances et les taches solaires. (Jan. 24. Read Feb. 3.)	'C. R.' lxxvi. 250–257.
Capt. Tupman .	Observations of the Solar Prominences.	'Monthly Not. Astr. Soc.' xxxiii. 105–115; 'Am. J.' v. 319 (Abs.)
C. Braun . .	Ueber directe Photographirung der Sonnen-Protuberanzen.	'Astron. Nachr.' lxxx. 34–42; 'Ann. Phys. u. Chem.' cxlviii. 475–488.
J. Janssen . .	Rapport à l'Académie relatif à l'observation de l'éclipse du 12 décembre 1871, observée à Shoolor (Indoustan).	'Ann. Chim. et Phys.' [4] xxviii. 474–499.
Zöllner . .	Ueber die Temperatur und physische Beschaffenheit der Sonne (Second Memoir). (Read Feb. 21.)	'Ber. der K. Sächs. Ges. der Wiss.' xxv. 158–194; 'Phil. Mag.' [4] xlvi. 290–304, 343–356.

Astronomical Applications, 1873.

C. S. Hastings .	Comparison of the Spectra of the Limb and of the Centre of the Sun, made at the Sheffield Scientific School. (April 3.)	'Am. J.' [3] v. 369–371; 'Nature,' viii. 77.
J. N. Lockyer . .	Researches in Spectrum-Analysis in connection with the Spectrum of the Sun. No. II. (Recd. Mar. 14. Read May 8.)	'Phil. Trans.' 1873, clxiii. 639–658; 'Proc. Roy. Soc.' xxi. 285–288 (Abs.); 'J. Chem. Soc.' [2] xi. 994–995 (Abs.); 'Phil. Mag.' [4] xlvi. 407–410 (Abs.); 'Ber.' vi. 973 (Abs.)
A. Secchi . .	Essai, pendant une éclipse solaire, de la nouvelle méthode spectroscopique proposée pour le prochain passage de Vénus. (May 27. Read June 2.)	'C. R.' lxxvi. 1327–1331.
J. N. Lockyer . .	Recherches d'Analyse spectrale au sujet du spectre solaire. (Read June 9.)	„ lxxvi. 1399–1403.
Janssen . . .	The Coronal Atmosphere of the Sun	'Nature,' viii. 127–129, 149–150.
A. Secchi . .	Nouvelle série d'observations sur les protubérances solaires; nouvelles remarques sur les relations qui existent entre les protubérances et les taches. (June 9. Read June 23.)	'C. R.' lxxvi. 1522–1526.
Tacchini . . .	Nouvelles observations constatant la présence du magnésium sur le bord entier du soleil. (June 23. Read June 30.)	„ lxxvi. 1577–1578.
„ . . .	Nouvelles observations spectrales, en désaccord avec quelques-unes des théories émises sur les taches solaires. (July 11. Read July 21.)	„ lxxvii. 195–198.
A. Secchi . .	Nouvelles recherches sur le diamètre solaire. (July 19. Read July 28.)	„ lxxvii. 253–260.
Wolf and Rayet .	Sur le spectre de la comète III de 1873. (Read Aug. 25.)	„ lxxvii. 529.
G. Rayet . . .	Sur le spectre de l'atmosphère solaire. (Read Aug. 25.)	„ lxxvii. 529–531.
G. Rayet and André	Sur les changements de forme et le spectre de la comète 1873 IV. (Read Sept. 1.)	„ lxxvii. 564–566.
H. Vogel . .	Ueber die Spectra der Cometen. (Sept. 1872.)	'Astron. Nachr.' lxxx. 183–188; 'Ann. Phys. u. Chem.' cxlix. 400–408; 'Nature,' ix. 193–194 (Abs.)
J. N. Lockyer .	Recherches sur l'analyse spectrale dans ses rapports avec le spectre solaire.	'Ann. Chim. et Phys.' [4] xxix. 430–432.

ASTRONOMICAL APPLICATIONS, 1873, 1874.

Tacchini . . .	Nouvelles observations relatives à la présence du magnésium sur le bord du Soleil, et réponse à quelques points de la théorie émise par M. Faye. (Aug. 27. Read Sept. 8.)	'C. R.' lxxvii. 606–609.
L. Respighi . .	Sur la grandeur des variations du diamètre solaire. (Read Sept. 29.)	'C. R.' lxxvii. 715–720.
" . .	Sur la grandeur et les variations du diamètre solaire. (Read Oct. 6.)	" lxxvii. 774–778 (Abs.)
A. Secchi . . .	Réponse à une note de M. Respighi sur la grandeur des variations du diamètre solaire. (Oct. 8. Read Oct. 27.)	" lxxvii. 904–907.
" . . .	Suites des Observations des protubérances solaires, pendant les six dernières rotations de l'astre du 23 avril au 2 octobre 1873; conséquences concernant la théorie des taches. (Oct. 17. Read Nov. 3.)	" lxxvii. 977–981.
H. E. Roscoe . .	Professor Young and the Presence of Ruthenium in the Chromosphere. (Nov. 4.)	'Nature,' ix. 5.
J. N. Lockyer . .	(Bakerian Lecture.) Researches in Spectrum-Analysis in connection with the Spectrum of the Sun. Part III. (Recd. Nov. 20. Read Nov. 27.)	'Phil. Trans.' 1874, clxiv. 479–494; 'Proc. Roy. Soc.' xxi. 508–514 (Abs.); 'J. Chem. Soc.' [2] xii. 495 (Abs.); 'Phil. Mag.' [4] xlvii. 384–390.
" . . .	Note préliminaire sur les éléments existant dans le Soleil. (Read Dec. 8.)	'C. R.' lxxvii. 1347–1352; 'Ber.' vi. 1554–1555 (Abs.); 'J. Chem. Soc.' [2] xii. 424–426 (Abs.)
H. Vogel . . .	Ueber das Spectrum des von Borelly am 20 August entdeckten Cometen, sowie über das des hellen von Henry am 23 August aufgefundenen Cometen. (Sept. 8, 1873.)	'Astron. Nachr.' lxxxii. 217–220; 'Am. J.' vi. 393–394 (Abs.)
J. M. Wilson and G. M. Seabroke.	Remarks on Spectroscopic Observations of the Sun, made at the Temple Observatory, Rugby School, in 1871–2–3. (Read Nov. 11.)	'Monthly Not. Astr. Soc.' xxxiv. 26–29.

1874.

W. H. M. Christie .	On the Colour and Brightness of Stars as measured with a new Photometer. (Jan. 8.)	'Monthly Not. Astr. Soc.' xxxiv. 111–120.
C. Montigny . .	La fréquence des variations de couleurs des étoiles dans la scintillation est généralement en rapport avec la constitution de leur lumière, d'après l'analyse spectrale. (Read Feb. 7.)	'Bull. de l'Acad. de Belgique,' [2] xxxvii. 165–190; 'Ann. Phys. u. Chem.' cliii. 277–298.
J. B. N. Hennessey .	Note on the Displacement of the Solar Spectrum. (Recd. Dec. 15, 1873. Read Feb. 26, 1874.)	'Proc. Roy. Soc.' xxii. 219–220; 'Phil. Mag.' [4] xlviii. 303–304.

ASTRONOMICAL APPLICATIONS, 1874.

J. B. N. Hennessey .	On White Lines in the Solar Spectrum. (Recd. Dec. 8, 1873. Read Feb. 26, 1874.)	'Proc. Roy. Soc.' xxii. 221–222; 'Phil. Mag.' [4] xlviii. 305–306.
A. Secchi . .	Observations des protubérances solaires pendant le dernier trimestre de l'année 1873. Résultats fournis par l'emploi des réseaux, au lieu de prismes, dans les observations spectrales des protubérances. (Feb. 24. Read Mar. 2.)	'C. R.' lxxviii. 606–612.
E. H. Pringle . .	Note on some Spectroscopic Observations of Sirius, γ Argûs, &c. (Jan. 27. Read Mar. 13.)	'Monthly Not. Astr. Soc.' xxxiv. 267–268.
J. N. Lockyer and G. M. Seabroke. .	Spectroscopic Observations of the Sun. (Recd. Feb. 2. Read Mar. 19.)	'Phil. Trans.' 1875, clxv. 577–586; 'Proc. Roy. Soc.' xxii. 247 (Abs.)
W. Huggins . .	On the Motions of some of the Nebulæ towards or from the Earth. (Recd. Jan 26. Read Mar. 26.)	'Proc. Roy. Soc.' xxii. 251–254; 'Am. J.' [3] viii. 75–77; 'Phil. Mag.' [4] xlviii. 471–474.
A. Secchi . .	Observations sur le spectre des comètes. (May 19. Read May 25.)	'C. R.' lxxviii. 1467–1469.
A. W. Wright . .	On the Spectrum of the Zodiacal Light. (June 5.)	'Am. J.' [3] viii. 39–46; 'Ann. Phys. u. Chem.' cliv. 619–629.
G. Rayet . . .	Note sur le spectre de la comète de Coggia (1874 III). (Read June 8.)	'C. R.' lxxviii. 1650–1652; 'Am. J.' [3] viii. 156–157 (Abs.)
J. N. Lockyer . .	Researches in Spectrum-Analysis in connection with the Spectrum of the Sun. No. IV. (Recd. May 11. Read June 18.)	'Phil. Trans.' 1874, clxiv. 805–813; 'Proc. Roy. Soc.' xxii. 391 (Abs.); 'Phil. Mag.' [4] xlix. 326 (Abs.)
A. Secchi. . .	Sur le spectre de la comète Coggia. (June 22. Read July 6.)	'C. R.' lxxix. 20.
J. N. Lockyer . .	The Comet	'Nature,' x. 179–181.
C. Montigny . .	Nouvelles recherches sur la fréquence de la scintillation des étoiles dans ses rapports avec la constitution de leur lumière d'après l'analyse spectrale. (Read Aug. 1.)	'Bull. de l'Acad. Roy. de Belgique' [2] xxxviii. 300–320; 'Ann. Phys. u. Chem.' Erg.-B. vii. 605–624.
A. Secchi. . .	Observations faites pendant les derniers jours de l'apparition de la comète Coggia. (July 26. Read Aug. 3.)	'C. R.' lxxix. 284–286.
Wolf and Rayet .	Note sur la comète de Coggia. (Read Aug. 10.)	„ lxxix. 369–371.
W. de Fonviel'e .	Note sur des observations spectroscopiques faites dans l'ascension du 24 sept. 1874, pour étudier les variations d'étendue des couleurs du spectre. (Read Oct. 5.)	„ lxxix. 816–817.

ASTRONOMICAL APPLICATIONS, 1874, 1875.

A. Secchi . .	Observation de l'éclipse solaire du 10 octobre 1874, avec le spectroscope. Tableaux des observations des protubérances solaires, du 26 décembre 1873 au 2 août 1874. (Oct. 11. Read Oct. 19.)	'C. R.' lxxix. 885–889.
A. Cornu . . .	Sur le spectre normal du Soleil.	'Ann. de l'École norm.' [2] iii. 421–434 ; 'Arch. de Genève,' [2] lii. 62–63 (Abs.)

1875.

J. N. Lockyer . .	Remarks on a New Map of the Solar Spectrum. (Recd. Nov. 13, 1874. Read Jan. 7, 1875.)	'Proc. Roy. Soc.' xxiii. 152–154 ; 'Am. J.' [3] ix. 307 (Abs.); 'Phil. Mag.' [4] l. 144–146.
W. Huggins . .	On the Spectrum of Coggia's Comet. (Recd. Nov. 13, 1874. Read Jan. 7, 1875.)	'Proc. Roy. Soc.' xxiii. 154–159.
J. Janssen . .	Die Chemie des Himmels . .	'Arch. Pharm.' 1875, 51.
J. B. N. Hennessey .	Appendix to Note dated November 1873, on White Lines in the Solar Spectrum. (Recd. Jan. 11. Read Feb 11.)	'Proc. Roy. Soc.' xxiii. 259–260.
A. Secchi . .	Étude des taches et des protubérances solaires de 1871 à 1875. (Read May 24.)	'C. R.' lxxx. 1273–1278.
S. P. Langley . .	Étude des radiations superficielles du Soleil. (Read Sept. 6.)	„ lxxxi. 436–439.
J. L. Soret . .	Sur la température du Soleil. (Oct. 14, 1874.)	'Arch. de Genève,' [2] lii. 89–95 ; 'Phil. Mag.' [4] l. 155–158.
A. Secchi . .	Résultats des observations de protubérances et des taches solaires du 23 avril 1871 au 28 juin 1875 (55 rotations). (Read Oct. 4 and 11.)	'C. R.' lxxxi. 563–566, 605–609.
G. Rayet . .	Sur le spectre de l'atmosphère solaire.	'J. Pharm. et Chim.' xix. 31–33 ; 'Archiv Pharm.' iv. 325–327.
G. B. Airy . .	Spectroscopic Observations made at the Royal Observatory, Greenwich. (Read Nov. 12.)	'Monthly Not. Astr. Soc.' xxxvi. 27–37.
A. T. Arcimis . .	Observations of the Zodiacal Light at Cadiz. (Read Nov. 12.)	'Monthly Not. Astr. Soc.' xxxvi. 48–51.
A. Crova . . .	Sur l'intensité calorifique de la radiation solaire et son absorption par l'atmosphère terrestre. (Read Dec. 13.)	'C. R.' lxxxi. 1205–1207.
S. P. Langley . .	The Solar Atmosphere, an introduction to an account of researches made at the Alleghany Observatory.	'Am. J.' [3] x. 489–497.

ASTRONOMICAL APPLICATIONS, 1876.

1876.

L. Trouvelot . .	On the Veiled Solar Spots. (Oct 1, 1875.)	'Proc. Am. Acad.' xi. 62–69; 'Am. J.' [3] xi. 169–176.
R. Amory . .	On Photographs of the Solar Spectrum. (Read May 25, 1875.)	'Proc. Am. Acad.' xi. 70.
A. Crova . . .	Sur la répartition de la radiation solaire à Montpellier pendant l'année 1875.	'C. R.' lxxxii. 375–377.
W. de W. Abney .	Preliminary Note on Photographing the Least Refrangible Portion of the Solar Spectrum. (Read Mar. 10.)	'Monthly Not. Astr. Soc.' xxxvi. 276–277; 'Phil. Mag.' [5] i. 414–415.
A. Secchi . .	Suite des observations des protubérances solaires pendant le second semestre de 1875. (March 22. Read March 27.)	'C. R.' lxxxii. 717–722.
,, . .	Sur le déplacement des raies dans les spectres des étoiles, produit par leur mouvement dans l'espace. (Mar. 25. Read April 3 and 10.)	'C. R.' lxxxii. 761–765, 812–814; 'Phil. Mag.' [5] i. 569–571.
F. Tisserand . .	Observations des taches du Soleil, faites à l'Observatoire de Toulouse en 1874 et 1875. (Read April 3.)	'C. R.' lxxxii. 765–767.
C. A. Young . .	Note on the Duplicity of the '1474' line in the Solar Spectrum. (April 19.)	'Am. J.' [3] xi. 429–431.
W. H. M. Christie .	Note on the Displacement of Lines in the Spectra of Stars. (Read May 12.)	'Monthly Not. Astr. Soc.' xxxvi. 313–317.
G. B. Airy . .	Spectroscopic Results for the Motions of Stars in the Line of Sight, obtained at the Royal Observatory, Greenwich. (Read May 12.)	'Monthly Not. Astr. Soc.' xxxvi. 318–326.
W. Huggins . .	Sur le déplacement des raies dans les spectres des étoiles produit par leur mouvement dans l'espace. (Read June 5.)	'C. R.' lxxxii. 1291–1293; 'Phil. Mag.' [5] ii. 72–74.
Tacchini . . .	Nouvelles observations relatives à la présence du magnésium sur le bord du Soleil. (Read June 12.)	'C. R.' lxxxii. 1385–1387; 'J. Chem. Soc.' 1876, ii. 588 (Abs.)
A. Secchi . .	Nouvelle série d'observations sur les protubérances et les taches solaires. (June 28. Read July 3.)	'C. R.' lxxxiii. 26–27.
,, . .	Nouvelles remarques sur la question du déplacement des raies spectrales dû au mouvement propre des astres. (Read July 10.)	,, lxxxiii. 117–119.
E. Becquerel . .	Sur l'observation de la partie infra-rouge du spectre solaire, au moyen des effets de phosphorescence. (Read July 24.)	'C. R.' lxxxiii. 249–255; 'J. Chem. Soc.' 1876, ii. 587 (Abs.); 'Beiblätter,' i. 55–57.

ASTRONOMICAL APPLICATIONS, 1876, 1877.

H. C. Vogel . .	Untersuchungen über die Spectra der Planeten. (May 1876.)	'Ann. Phys. u. Chem.' clviii. 461–472.
C. A Young . .	Observations on the Displacement of lines in the Solar Spectrum caused by the Sun's Rotation. (Sept. 12.)	'Am. J.' [3] xii. 321–328; 'Beiblätter,' i. 53–54; (Abs.)
G. B. Airy . .	Spectroscopic Results for the Motion of Stars, and of Venus in the Line of Sight, and for the Rotation of the Sun and of Jupiter, made at the Royal Observatory, Greenwich. (Read Nov. 10.)	'Monthly Not. Astr. Soc.' xxxvii. 22–36.
A. Cornu . . .	Sur le spectre de l'étoile nouvelle de la constellation du Cygne. (Read Dec. 11.)	'C. R.' lxxxiii. 1172–1174; 'Nature,' xv. 158–159.
W. Huggins . .	Note on the Photographic Spectra of Stars. (Recd. Dec. 6. Read Dec. 14.)	'Proc. Roy. Soc.' xxv. 445–446; 'Phil. Mag.' [5] iii. 527–528; 'Am. J.' [3] xiii. 324–325.
" . .	Note préliminaire sur les photographies des spectres stellaires. (Read Dec. 18.)	'C. R.' lxxxiii. 1229–1230.

1877.

E. Becquerel . .	Sur l'observation de la partie infrarouge du spectre solaire, au moyen des effets de phosphorescence.	'Ann. Chim. et Phys.' [5] x. 5–13.
A. Secchi . .	Étude spectroscopique de la nouvelle étoile signalée par M. Schmidt. (Read Jan. 15.)	'C. R.' lxxxiv. 107–108.
H. Draper . .	Photographs of the Spectra of Venus and α Lyræ. (Dec. 1876.)	'Nature,' xv. 218; 'Am. J.' [3] xiii. 95; 'Phil. Mag.' [5] iii. 238.
T. W. Backhouse .	Spectrum of New Star. (Jan. 26)	'Nature,' xv. 295–296.
Three letters by H. Vogel, R. Copland, A. Secchi	The New Star in Cygnus . .	'Astron. Nachr.' lxxxix. 37–40; lxxxix. 63; xc. 351–352; 'Nature,' xv. 315–316; 'Am. J.' [3] xv. 76–77.
J. W. Draper . .	On the Fixed Lines in the Ultrared Invisible Region of the Spectrum. (Dec. 13, 1876.)	'Phil. Mag.' [5] iii. 86–89; 'Beiblätter,' i. 239–240 (Abs.)
A. Secchi . .	Sur un nouveau catalogue d'étoiles colorées et sur le spectre de l'étoile de Schmidt. (Read Feb. 12.)	'C. R.' lxxxiv. 290–291.
J. N. Lockyer . .	Researches in Spectrum-Analysis in connection with the Spectrum of the Sun. No. V. (Recd. Jan 10. Read Feb. 15.)	'Proc. Roy. Soc.' xxv. 546 (Abs.)
H. W. Vogel . .	Ueber die Photographie der weniger brechbaren Theile des Sonnenspectrums. (Jan. 1877.)	'Ann Phys. u. Chem.' clx. 292–296.
E. Becquerel . .	Sur l'observation de la partie infrarouge du spectre solaire au moyen des effets de phosphorescence.	'Arch. de Genève,' [2] lvii. 306–318; 'Am. J.' [3] xiii. 379–380 (Abs.)

Astronomical Applications, 1877.

E. Becquerel	The New Star in Cygnus	'Monthly Not. Astr. Soc.' xxxvii. 200–202; 'Am. J.' [3] xiii. 395–397.
A. Secchi	Observations des protubérances solaires pendant le second semestre de 1876. Rotations lxix à lxxv. (Read March 5.)	'C. R.' lxxxiv. 423–427.
"	Observations du spectre de la comète Borelly.	" lxxxiv. 427.
H. C. Vogel	Spectral-Photometrische Untersuchungen insbesondere zur Bestimmung der Absorption der die Sonne umgebenden Gashülle. (Read Mar. 8.)	'Monatsb. Berl. Akad.' 1877, 104–142.
W. de W. Abney	Effect of a Star's Rotation on its Spectrum. (Read Mar. 9.)	'Monthly Not. Astr. Soc.' xxxvii. 278–279.
"	On Fixed Lines in the Ultra-red Region of the Spectrum.	'Phil. Mag.' [5] iii. 222; 'Beiblätter,' i. 239–240.
E. J. Stone	On a Cause for the Appearance of Bright Lines in the Spectra of Irresolvable Star-Clusters. (Recd. March 20. Read April 19.)	'Proc. Roy. Soc.' xxvi. 156–157.
W. Huggins	On the Inferences to be drawn from the Appearance of Bright Lines in the Spectra of Irresolvable Nebulæ. (Recd. April 26. Read April 26.)	'Proc. Roy. Soc.' xxvi. 179–181.
Wolf	Observations des comètes II (Winnecke) et III (Swift-Borelly). (Read April 30.)	'C. R.' lxxxiv. 929–931.
Tacchini	Sur les taches solaires. (Read May 14.)	" lxxxiv. 1079–1081.
A. Secchi	Sur le spectre de la comète de Winnecke. (May 23. Read June 4.)	'C. R.' lxxxiv. 1289–1292.
Lord Lindsay	On the Spectra of the Comets *b.* and *c.* 1877. (May 8. Read June 8.)	'Monthly Not. Astr. Soc.' xxxvii. 430–432.
A. Secchi	Sur l'état actuel de l'atmosphère solaire. (June 10. Read June 18.)	'C. R.' lxxxiv. 1430–1434.
Tacchini	Sur les éruptions métalliques solaires observées à Palerme depuis 1871 jusqu'en avril 1877. (Read June 18.)	" lxxxiv. 1448–1450.
"	Sur une tache solaire observée pendant le mois de juin 1877. (Read June 25.)	" lxxxiv. 1500–1501.
H. Draper	Discovery of Oxygen in the Sun by Photography, and a new Theory of the Solar Spectrum.	'Am. J.' [3] xiv. 89–96; 'Nature,' xvi. 364–367; 'C. R.' lxxxv. 613–614 (Abs.); 'J. Chem. Soc.' xxxiv. 101 (Abs.); 'Beiblätter,' ii. 86–90 (Abs.)
Piazzi Smyth	Optical Spectroscopy of the Red End of the Solar Spectrum.	'Nature,' xvi. 264.

ASTRONOMICAL APPLICATIONS, 1877, 1878.

J. H. Gladstone .	On Some Points connected with the Chemical Constituents of the Solar System.	'Phil. Mag.' [5] iv. 379–385; 'J. Chem. Soc.' xxxiv. 189 (Abs.)
G. B. Airy . .	On the Spectrum of Comet *b*. 1877 (Winnecke's) and of the Eclipsed Moon, observed at the Royal Observatory, Greenwich. (Aug. 28.)	'Monthly Not. Astr. Soc.' xxxvii. 469–470.
.	The Spectrum of Nova Cygni .	'Nature,' xvi. 400–403.
J. B. N. Hennessey .	Optical Spectroscopy of the Red End of the Solar Spectrum. (Oct. 3.)	„ xvii. 28–29.
G. B. Airy . .	On the Spectrum of a Solar Spot observed at the Royal Observatory, Greenwich. (Read Nov. 9.)	'Monthly Not. Astr. Soc.' xxxviii. 32–33.
W. Noble . .	Note on the Spectrum of the Eclipsed Moon. (Read Nov. 9.)	'Monthly Not. Astr. Soc.' xxxviii. 34.
G. B. Airy . .	Physical Observations of Mars, made at the Royal Observatory, Greenwich. (Read Nov. 9.)	'Monthly Not. Astr. Soc.' xxxviii. 34–38.
A. Schuster . .	On the Presence of Oxygen in the Sun. (Nov. 30.)	'Nature,' xvii. 148–149; 'Beiblätter,' ii. 90–91 (Abs.)
R. Meldola . .	Oxygen in the Sun. (Dec. 21.) .	'Nature,' xvii. 161–162; 'Beiblätter,' ii. 91 (Abs.)
E. J. Stone . .	On a Cause for the Appearance of Bright Lines in the Spectra of Irresolvable Star-Clusters. (Recd. Aug. 13. Read Dec. 13.)	'Proc. Roy. Soc.' xxvi. 517–519; 'Monthly Not. Astr. Soc.' xxxviii. 106–108.
J. N. Lockyer .	Researches in Spectrum Analysis in connection with the Spectrum of the Sun. (Recd. Nov. 17, 1877. Read Jan. 24, 1878.)	'Proc. Roy. Soc.' xxvii. 49–50.
J. N. Lockyer and A. Schuster.	Report on the Total Solar Eclipse of April 6, 1875. (Recd. June 19.)	'Phil. Trans.' 1878, clxix. 139–154.

1878.

A. Secchi . .	Observations des protubérances solaires pendant le premier semestre de l'année 1877. (Read Jan. 14.)	'C. R.' lxxxvi. 98–100.
A. Cornu . .	Étude du spectre solaire ultra-violet. (Read Jan. 14.)	'C. R.' lxxxvi. 101–104; 'Beiblätter,' ii. 339–340 (Abs.)
J. N. Lockyer . .	Note on the Bright Lines in the Spectra of Stars and Nebulæ. (Recd. Dec. 31, 1877. Read Jan. 24, 1878.)	'Proc. Roy. Soc.' xxvii. 50–51.
E. Trouvelot . .	Sudden extinction of the light of a Solar Protuberance. (Jan. 12, 1877.)	'Am. J.' [3] xv. 85–88.
A. Cornu . .	Sur les raies sombres du spectre solaire et la constitution du Soleil. (Read Feb. 4.)	'C. R.' lxxxvi. 315–317; 'J. Chem. Soc.' xxxiv. 357 (Abs.)

Astronomical Applications, 1878.

J. N. Lockyer . .	Les éléments présents dans la couche du Soleil qui produit le renversement des raies spectrales. (Read Feb. 4.)	'C. R.' lxxxvi. 317–321; 'J. Chem. Soc.' xxxiv. 357 (Abs.)
	D'Arrest's Spectroscopical Researches.	'Nature,' xvii. 311–313.
H. Draper . .	Oxygen in the Sun. (Jan. 28.)	" xvii. 339–340.
J. N. Lockyer . .	Researches in Spectrum-Analysis in connection with the Spectrum of the Sun. (Recd. Nov. 17, 1877. Read Jan. 24, 1878.)	'Proc. Roy. Soc.' xxvii. 279–284.
A. Cornu . .	Sur quelques conséquences de la constitution du spectre solaire. (Read Feb. 25.)	'C. R.' lxxxvi. 530–533; 'Beiblätter,' ii. 231–232 (Abs.)
W. A. Norton . .	Coggia's Comet—its Physical Condition and Structure. Physical Theory of Comets.	'Am. J.' [3] xv. 161–177.
Piazzi Smyth . .	Colour in Practical Astronomy, Spectroscopically Examined. (May 24.)	'Trans. Roy. Soc. Edin.' xxviii. 779–843; 'Beiblätter,' iv. 548–549 (Abs.)
Tacchini . .	Résultats des observations faites en 1877 au bord du Soleil sur les raies *b* et 1474*k*. (Read Mar. 25.)	'C. R.' lxxxvi. 756–758.
J. N. Lockyer . .	Note on the Existence of Carbon in the Coronal Atmosphere of the Sun. (Recd. Mar. 20. Read April 11.)	'Proc. Roy. Soc.' xxvii. 308–309; 'J. Chem. Soc.' xxxviii. 429 (Abs.)
W. de W. Abney .	Photography of the Least Refrangible End of the Solar Spectrum. (Read April 12.)	'Monthly Not. Astr. Soc.' xxxviii. 348–351; 'Phil. Mag.' [5] vi. 154–157.
Tacchini . .	Observations des taches et des protubérances solaires pendant le premier trimestre de 1878. (Read April 22.)	'C. R.' lxxxvi. 1008–1009.
J. N. Lockyer . .	Recent Researches in Solar Chemistry. (Read May 11.)	'Proc. Phys. Soc.' ii. 308–325; 'Phil. Mag.' [5] vi. 161–176; 'Beiblätter,' iii. 353–354 (Abs.)
" . .	Researches in Spectrum-Analysis in connection with the Spectrum of the Sun. No. V. (Recd. April 29. Read May 23.)	'Proc. Roy. Soc.' xxvii. 409 (Abs.)
R. Meldola . .	On a Cause for the Appearance of Bright Lines in the Solar Spectrum. (June 6.)	'Phil. Mag.' [5] vi. 50–61; 'Am. J.' [3] xvi. 290–300; 'Beiblätter,' ii. 561–562 (Abs.); 'J. Chem. Soc.' xxxvi. 574–575 (Abs.)
W. H. M. Christie .	On the Existence of Bright Lines in the Solar Spectrum. (June 13. Read June 14.)	'Monthly Not. Astr. Soc.' xxxviii. 473–474.
G. B. Airy . .	Spectroscopic Results for the Motions of Stars in the Line of Sight, made at the Royal Observatory, Greenwich. (June 14.)	'Monthly Not. Astr. Soc.' xxxviii. 493–508.

ASTRONOMICAL APPLICATIONS, 1878.

Tacchini . . .	Résultats des observations solaires, pendant le deuxième trimestre de 1878. (Read Aug. 5.)	'C. R.' lxxxvii. 257–259.
J. N. Lockyer . .	The Eclipse. (Aug. 8) . . .	'Nature,' xviii. 457–462.
H. Draper . .	The Eclipse	„ xviii. 462–464.
„ . .	The Solar Eclipse of July 29, 1878	'Am. J.' [3] xvi. 227–230; 'Phil. Mag.' [5] vi. 318–320.
J. C. Draper . .	On the presence of Dark Lines in the Solar Spectrum which correspond closely to the lines of the Spectrum of Oxygen.	'Am. J.' [3] xvi. 256–265; 'Nature,' xviii. 654–657; 'Beiblätter,' iii. 188–190 (Abs.); 'J. Chem. Soc.' xxxvi. 997.
C. A. Young . .	Observations upon the Solar Eclipse of July 29, 1878, by the Princeton Eclipse Expedition. (Sept. 6.)	Am. J.' [3] xvi. 279–290.
H. F. Blanford .	Janssen's New Method of Solar Photography.	'Nature,' xviii. 643–645.
W. T. Sampson .	On the Spectrum of the Corona. (Aug. 31, 1871.)	'Am. J.' [3] xvi. 343–345; 'Beiblätter,' iii. 277 (Abs.)
S. P. Langley . .	On Certain Remarkable Groups in the Lower Spectrum.	'Proc. Am. Acad.' xiv. 92–105; 'Beiblätter,' iv. 208 (Abs.)
J. W. Backhouse .	On the Spectrum of the New Star in Cygnus. (June 3. Read Nov. 8.)	'Monthly Not. Astr. Soc.' xxxix. 34–37.
Piazzi Smyth . .	Measures of the great B Line in the Spectrum of a High Sun. (Nov. 4 and 22.)	'Monthly Not. Astr. Soc.' xxxix. 38–43.
A. Schuster . .	Some Remarks on the Total Solar Eclipse of July 29, 1878. (Read Nov. 8.)	'Monthly Not. Astr. Soc.' xxxix. 44–47.
J. N. Lockyer . .	Researches in Spectrum Analysis in connection with the Spectrum of the Sun. No. VII. (Recd. Dec. 11. Read Dec. 12.)	'Proc. Roy. Soc.' xxviii. 157–180; 'Am. J.' [3] xvii. 93–116; 'Beiblätter,' iii. 88–113; 'Nature,' xix. 197–201, 225–230; 'Ann. Chim. et Phys.' [5] xvi. 107–144; 'Chem. News,' xxxix. 1–5, 11–16.
Ferrari . . .	Sur les taches et protubérances solaires observées à l'équatorial du Collège romain. (Read Dec. 16.)	'C. R.' lxxxvii. 971–973.
Tacchini . . .	Résultats des observations solaires faites pendant le troisième trimestre de 1878. (Read Dec. 23.)	'C. R.' lxxxvii. 1031–1033.
Piazzi Smyth . .	The Solar Spectrum in 1877–1878 with some practical idea of its probable temperature of origination.	'Trans. Roy. Soc. Edin.' xxix. 285–342; 'Beiblätter,' iv. 276–277 (Abs.)

ASTRONOMICAL APPLICATIONS, 1879.

1879.

P. Tacchini . .	Protuberanze solari osservate a Palermo nel quarto trimestre del 1878.	'Mem. Spettr. ital.' viii. 10–11.
" . .	Riassunto delle protuberanze e delle macchie solari osservate alla Specola del Collegio Romano nel mese di Settembre, Ottobre, Novembre e Dicembre.	'Mem. Spettr. ital.' viii. 13–16.
J. N. Lockyer . .	Preliminary Note on the Substances which produce the Chromospheric Lines. (Recd. Dec. 24, 1878. Read Jan. 23, 1879.)	'Proc. Roy. Soc.' xxviii. 283–284; 'Nature,' xix. 292; 'Am. J.' [3] xvii. 250; 'Beiblätter,' iii. 420–422 (Abs.)
G. F. Barker . .	On the Results of the Spectroscopic Observation of the Solar Eclipse of July 29, 1878. (Aug. 10.)	'Am. J.' xvii. 121–125.
J. N. Lockyer . .	Recherches sur les rapports de l'analyse spectrale avec le spectre du soleil. (Read Jan. 27.)	'C. R.' lxxxviii. 148–154: 'J. Chem. Soc.' xxxvi. 575–576 (Abs.)
L. Thollon . .	Déplacement de raies spectrales, dû au mouvement de rotation du Soleil. (Read Jan. 27.)	'C. R.' lxxxviii. 169–171; 'Beiblätter,' iii. 355–356 (Abs.): 'J. Chem. Soc.' xxxvi. 574 (Abs.)
A. Cornu. . .	Sur le spectre normal du Soleil; partie ultra-violette. Deuxième partie.	'Ann. de l'école norm.' [2] ix. 21–106; 'Beiblätter,' iv. 371–374 (Abs.)
G. F. B. . . .	Note on J. C. Draper's paper 'On the presence of Dark Lines in the Solar Spectrum which correspond closely to the lines of the Spectrum of Oxygen.'	'Am. J.' [3] xvii. 162–166; 'Nature,' xix. 352–353; 'Beiblätter,' iii. 188–190 (Abs.)
C. W. Zenger . .	Photographie directe des protubérances solaires sans l'emploi du spectroscope. (Read Feb. 24.)	'C. R.' lxxxviii. 374–375.
J. N. Lockyer . .	Discussion of 'Young's List of Chromospheric Lines.' (Recd. Mar. 5. Read Mar. 20.)	'Proc. Roy. Soc.' xxviii. 432–444; 'Beiblätter,' iii. 420–422 (Abs.)
Von Konkoly . .	Vorläufige Anzeige über das Spectrum des Brorsen'schen Cometen. (Mar. 20.)	'Astron. Nachr.' xciv. 335–336.
P. Tacchini . .	Macchie solari e facole osservate a Palermo nei mesi di gennaio, febbraio e marzo 1879.	'Mem. Spettr. ital.' viii. 35–36.
J. Macagno . .	Confronto fra la radiazione e l'intensità chimica della luce del sole. (March 31.)	'Mem. Spettr. ital.' viii. App. 13–18.
P. Tacchini . .	Osservazioni solari dirette e spettroscopiche fatte a Palermo nel 1° trimestre del 1879.	'Mem. Spettr. ital.' viii. 37–40.
G. D. Liveing and J. Dewar.	Note on the unknown Chromospheric Substance of Young. (Recd. Mar. 27. Read April 3.)	'Proc. Roy. Soc.' xxviii. 475–477; 'Beiblätter,' iii. 709 (Abs.)
T. Bredischin . .	Spectrum des Brorsen'schen Cometen. (April 4.)	'Astron. Nachr.' xcv. 15–16.

ASTRONOMICAL APPLICATIONS, 1879.

W. H. Pulsifer .	On a Method of Estimating the Thickness of Young's Reversing Layer.	'Am. J.' [3] xvii. 303.
C. A. Young . .	Note on the Spectrum of Brorsen's Comet. (April 5.)	'Am. J.' [3] xvii. 373–375; 'Nature,' xix. 559; 'Phil. Mag.' [5] viii. 178–179.
Houzeau and Montigny.	Sur un travail de M. l'abbé Spée concernant le déplacement des raies des spectres d'étoiles. (Read April 5.)	'Bull. de l'Acad. de Belgique,' xlvii. 318–324.
E. L. Trouvelot	Observations of Absorbing Vapours upon the Sun. (Jan. 12. Read April 9.)	'Monthly Not. Astr. Soc.' xxxix. 374–379.
W. Huggins . .	On the Spectrum of Brorsen's Comet	'Nature,' xix. 579.
W. H. M. Christie .	On the Spectrum of Brorsen's Comet. (April 21.)	'Nature,' xx. 5; 'Am. J.' [3] xvii. 496–497.
W. M. Watts . .	Brorsen's Comet. (May 5) . .	'Nature,' xx. 27–28.
T. W. Backhouse .	Brorsen's Comet. (May 6) . .	„ xx. 28.
G. B. Airy . .	On the Spectrum of Brorsen's Comet, observed at the Royal Observatory, Greenwich. (Read May 9.)	'Monthly Not. Astr. Soc.' xxxix. 428–430.
Lord Lindsay . .	Observations of Brorsen's Comet. (May 7. Read May 9.)	'Monthly Not. Astr. Soc.' xxxix. 430.
W. H. M. Christie .	Spectrum of Brorsen's Comet. (May 17.)	'Nature,' xx. 75.
J. N. Lockyer . .	Note on a recent Communication of Messrs. Liveing and Dewar. (Recd. April 30. Read May 15.)	'Proc. Roy. Soc.' xxix. 45–47; 'Beiblätter,' iii. 710–711 (Abs.)
A. Cornu . . .	Sur la Limite Ultra-violette du Spectre Solaire. (Recd. May 15. Read May 15.)	'Proc. Roy. Soc.' xxix. 47–55; 'C. R.' (June 2) lxxxviii. 1101 – 1108; 'J. Chem. Soc.' xxxvi. 861 (Abs.); 'Beiblätter,' iv. 39–40 (Abs.)
W. M. Watts . .	The Spectrum of Brorsen's Comet. (May 27.)	'Nature,' xx. 94.
Tacchini . .	Observations solaires pendant le premier trimestre de l'année 1879. (Read June 2.)	'C. R.' lxxxviii. 1131–1132.
J. C. Draper . .	On the Dark Lines of Oxygen in the Solar Spectrum on the less refrangible side of G.	'Am. J.' [3] xvii. 448–452; 'J. Chem. Soc.' xxxviii. 201 (Abs.); 'Beiblätter,' iii. 872–873 (Abs.)
H. Draper . .	On the Coincidence of the Bright Lines of the Oxygen Spectrum with Bright Lines in the Solar Spectrum. (June 10. Read June 13.)	'Monthly Not. Astr. Soc.' xxxix. 440–447; 'Am. J.' [3] xviii. 262–276; 'Beiblätter,' iv. 275–276 (Abs.)
G. M. Seabroke .	Spectroscopic Observations of the Motion of Stars in the line of Sight, made at the Temple Observatory, Rugby. (Read June 13.)	'Monthly Not. Astr. Soc.' xxxix. 450–453.

ASTRONOMICAL APPLICATIONS, 1879.

G. D. Liveing and J. Dewar.	Note on 'Spectroscopic Papers.' (Recd. May 29. Read June 19.)	'Proc. Roy. Soc.' xxix. 166–168; 'Beiblätter,' iv. 38 (Abs.)
J. N. Lockyer . .	Report to the Committee on Solar Physics on the Basic Lines common to Spots and Prominences. (Recd. June 19. Read June 19.)	'Proc. Roy. Soc.' xxix. 247–265; 'Beiblätter,' iv. 45 (Abs.)
Thollon . . .	Dessin du spectre solaire. (Read June 23.)	'C. R.' lxxxviii. 1305–1307.
J. N. Lockyer . .	Preliminary Note on the Substances which produce the Chromospheric Lines.	'Am J.' [3] xviii. 158–159.
Von Konkoly . .	Spectroscopische Beobachtung des Cometen Brorsen. (June 30.)	'Astron. Nachr.' xcv. 193–196.
P. Tacchini . .	Macchie solari e facole osservate a Palermo e Roma nel secondo trimestre del 1879.	'Mem. Spettr. ital.' viii. 50–51.
„ . .	Osservazioni solari dirette e spettroscopiche fatte a Palermo e Roma nel secondo trimestre del 1879.	'Mem. Spettr. ital.' viii. 52–54.
„ . .	Note sulle faccole e macchie . .	'Mem. Spettr. ital.' viii. 55–56.
„ . .	Sull' andamento dell' attività solare dal 1871 al 1878.	'Mem. Spettr. ital.' viii. 65–72.
„ . .	Observations du Soleil pendant le deuxième trimestre de l'année 1879. (Sept. 5. Read Sept. 15.)	'C. R.' lxxxix. 519–520.
H. Draper . .	On Photographing the Spectra of Stars and Planets.	'Am. J.' [3] xviii. 419–425; 'Nature,' xxi. 83–85; 'Beiblätter,' iv. 374 (Abs.)
Von Konkoly . .	Spectroscopische Beobachtung des Cometen Palisa. (Oct. 12.)	'Astron. Nachr.' xcvi. 39–42.
H. W. Vogel . .	Die Photographie des Wasserstoffspectrums und der Sternspectra.	'Photog. Mittheilungen,' xvi. 276–278.
J. C. Draper . .	On a Photograph of the Solar Spectrum, showing Dark Lines of Oxygen.	'Monthly Not. Astr. Soc.' xl. 14–17.
Lord Lindsay . .	Observations of the Spectrum of Comet 1879 *d* (Palisa). (Nov. 11. Read Nov. 14.)	'Monthly Not. Astr. Soc.' xl. 23–25.
A. Cornu . . .	Observation de la limite ultra-violette du spectre solaire à diverses altitudes. (Read Nov. 17.)	'C. R.' lxxxix. 808–814; 'J. Chem. Soc.' xxxviii. 201 (Abs.); 'Beiblätter,' iv. 207 (Abs.); 'Am. J.' [3] xix. 406 (Abs.)
L. Thollon . .	Taches et protubérances solaires observées avec un spectroscope à grande dispersion. (Read Nov. 17.)	'C. R.' lxxxix. 855–858; 'Beiblätter,' iv. 277 (Abs.)
Lord Lindsay . .	Note on the Spectrum of the Red Spot on Jupiter. (Sept. 26. Read Dec. 12.)	'Monthly Not. Astr. Soc.' xl. 87–88; 'Beiblätter,' iv. 614 (Abs.)

ASTRONOMICAL APPLICATIONS, 1879, 1880.

Lord Lindsay . .	Note on the Rev. T. W. Webb's New Nebula. (Read Dec. 12.)	'Monthly Not. Astr. Soc.' xl. 91; 'Beiblätter,' iv. 614–615 (Abs.)
Winnecke . .	The Nebula in Cygnus. (Nov. 30. Read Dec. 12.)	'Monthly Not. Astr. Soc.' xl. 92.
W. Huggins . .	On the Photographic Spectra of Stars. (Recd. Dec. 11. Read Dec. 18.)	'Phil. Trans.' 1880, clxxi. 669–690; 'Proc. Roy. Soc.' xxx. 20–22 (Abs.); 'Nature,' xxi. 269–270; 'Beiblätter,' iv. 467–468 (Abs.); 'Am. J.' [3] xix. 373–375 (Abs.); 'J. Chem. Soc.' xl. 485–486 (Abs.)
P. Tacchini and E. Millosevich	Macchie solari e facole osservate in Roma all' Equatoriale di Cauchoix nel terzo trimestre del 1879.	'Mem. Spettr. ital.' viii. 73–74.
E. Barbieri . .	Quadri statistici delle protuberanze e macchie solari osservate all' Collegio Romano nel 1° semestre, 1879.	'Mem. Spettr. ital.' viii. 75–80.
J. Janssen . .	Notice sur les progrès récents de la physique solaire.	'Annuaire du Bureau des Longitudes,' 1879, 623–685; 'Beiblätter,' iv. 277 (Abs.)

1880.

W. de W. Abney .	On the Photographic Method of Mapping the Least Refrangible End of the Solar Spectrum (with a Map of the Spectrum from 7,600 to 10,750. Bakerian Lecture). (Jan. 8.)	'Phil. Trans.' 1880, clxxi. 653–667; 'Proc. Roy. Soc.' xxx. 67 (Abs.); 'Beiblätter,' iv. 375 (Abs.); v. 507–509 (Abs.)
P. Tacchini and E. Millosevich	Macchie solari e facole osservate a Roma nell' ultimo trimestre, 1879.	'Mem. Spettr. ital.' viii. 88–89.
P. Tacchini . .	Sulle macchie solari e facole osservate all' Equatoriale di Cauchoix dell' osservatorio del Collegio Romano in Roma durante il terzo e quarto trimestre, 1879.	'Mem. Spettr. ital.' viii. 90–92.
" . .	Note sulle facole e macchie registrate nel 3° e 4° trimestre, 1879.	'Mem. Spettr. ital.' viii. 97–101.
" . .	Osservazioni solari dirette e spettroscopiche fatte a Roma nel terzo e quarto trimestre del 1879.	'Mem. Spettr. ital.' viii. 93–97, 102–104.
" . .	Le fotografie del sole fatte all' osservatorio di Meudon dal Professor Janssen.	'Mem. Spettr. ital.' ix. 1–5.
" . .	Disegni delle protuberanze, delle macchie, delle eruzioni e facole del Sole fatti a Roma dal giugno a dicembre 1879.	'Mem. Spettr. ital.' iv. 5–7.
W. Huggins . .	Sur les spectres photographiques des étoiles. (Read Jan. 12.)	'C. R.' xc. 70–73; 'Am. J.' [3] xix. 317–318.
L. Thollon . .	Cyclone solaire. (Read Jan. 12) .	'C. R.' xc. 87–89.

ASTRONOMICAL APPLICATIONS, 1880.

W. de W. Abney	Sur la photographie de la portion infra-rouge du spectre solaire. (Read Jan. 26.)	'C. R.' xc. 182–183; 'J. Chem. Soc.' xxxviii. 429 (Abs.); 'Beiblätter,' iv. 375 (Abs.)
P. Tacchini and E. Millosevich	Macchie solari e facole osservate a Roma nel mese di gennaio, 1880.	'Mem. Spettr. Ital.' ix. 8.
H. C. Vogel	Ueber das Spectrum des von Webb entdeckten Nebels im Schwan und eines neuen von Baxendell aufgefundenen Sternes im kleinen Hund. (Feb. 9.)	'Astron. Nachr.' xcvi. 287–288; 'Beiblätter,' iv. 468 (Abs.)
Tacchini	Observations des taches et protubérances solaires pendant les troisième et quatrième trimestres de 1879. (Read Feb. 23.)	'C. R.' xc. 358–360.
H. C. Vogel	Note on the Spectrum of Mr. Baxendell's New Star in Canis Minor. (Feb. 10.)	'Monthly Not. Astr. Soc.' xl. 294.
Lord Lindsay	Supplementary Note to the Paper of Dr. Vogel.	'Monthly Not. Astr. Soc.' xl. 294.
E. Conche	Sur la photographie du spectre solaire. (Read Mar. 22.)	'C. R.' xc. 689–690; 'Beiblätter,' iv. 374–375 (Abs.)
A. Riccò	Osservazioni solari dirette e spettroscopiche eseguite nel R. osservatorio di Palermo.	'Mem. Spettr. Ital.' ix. 25–36.
W. Huggins	L'intensité relative des raies spectrales de l'hydrogène et de l'azote en rapport avec la constitution des nébuleuses. (Read April 3.)	'Bull. de l'Acad. de Belgique' [2] xlix. 266–267; 'Beiblätter,' iv. 658 (Abs.)
P. Tacchini	Macchie solari e facole osservate a Romano nei mesi di febbraio e marzo, 1880.	'Mem. Spettr. Ital.' ix. 45–48.
W. Harkness	On the Solar Corona. (Read April 10.)	'Bull. Phil. Soc. Wash.' iii. 116–119; 'Beiblätter,' v. 128 (Abs.)
A. Cornu	Sur la loi de répartition suivant l'altitude de la substance absorbant dans l'atmosphère les radiations solaires ultra-violettes. (Read April 26.)	'C. R.' xc. 940–946; 'Beiblätter,' iv. 727–728 (Abs.)
L. Trouvelot	Spectres fugitifs observés près du limbe solaire.	'Ann. Chim. et Phys.' [5] xix. 433–449; 'Beiblätter,' iv. 727 (Abs.)
P. Tacchini	Osservazioni solari spettroscopiche e dirette fatte a Roma nel 1° trimestre dal 1880.	'Mem. Spettr. Ital.' ix. 49–58.
E. Spee	Sur la raie dite de l'Hélium. (Read May 11.)	'Bull. de l'Acad. de Belgique' [2] xlix. 379–396; 'Beiblätter,' iv. 614 (Abs.)
H. Draper	On a Photograph of Jupiter's Spectrum, showing Evidence of Intrinsic Light from that Planet. (Read May 14.)	'Monthly Not. Astr. Soc.' xl. 433–435; 'Am. J.' [3] xx. 118–120.

ASTRONOMICAL APPLICATIONS, 1880.

J. M. Lockyer . .	On a New Method of Spectrum Observation.	'Am. J.' [3] xix. 303-311.
Piazzi Smyth . .	Three Years' Experimenting in Mensurational Spectroscopy.	'Nature,' xxii. 193-195, 222-225.
A. Riccò . . .	Osservazioni solari dirette e spettroscopiche eseguite nel R. osservatorio di Palermo nel II° trimestre, 1880.	'Mem. Spettr. ital.' ix. 61-90.
P. Tacchini . .	Macchie solari e facole osservate a Roma nei mesi di aprile e maggio.	'Mem. Spettr. ital.' ix. 91-92.
J. Janssen . .	Sur la photographie de la chromosphère. (Read July 5.)	'C. R.' xci. 12; 'Beiblätter,' iv. 615 (Abs.)
S. P. Langley . .	Observations on Mount Etna . .	'Am. J.' [3] xx. 33-34; 'Beiblätter,' iv. 790 (Abs.)
Tacchini . . .	Sur la cause des spectres fugitifs observés par M. Trouvelot sur la limbe solaire. (Read July 19.)	'C. R.' xci. 156-158; 'Beiblätter,' iv. 727 (Abs.)
C. Fiévez . .	Recherches sur le spectre du magnésium en rapport avec la constitution du Soleil. (Read Aug. 7.)	'Bull. de l'Acad. de Belgique' [2] l. 91-98; 'Beiblätter,' iv. 789-790 (Abs.)
Tacchini . . .	Résultats des observations de taches et facules solaires pendant les deux premiers trimestres de 1880. (Read Aug. 9.)	'C. R.' xci. 316-317.
L. Thollon . .	Observation faite sur un groupe de raies dans le spectre solaire. (Read Aug. 16.)	'C. R.' xci. 368-370; 'J. Chem. Soc.' xl. 333 (Abs.); 'Beiblätter,' iv. 790-791 (Abs.); 'Am. J.' [3] xx. 430.
A Riccò . . .	Eruzione solare metallica del 31 luglio, 1880, osservata a Palermo.	'Mem. Spettr. ital.' ix. 96-100.
P. Tacchini . .	Osservazioni solari dirette e spettroscopiche fatte a Roma nel secondo trimestre del 1880.	'Mem. Spettr. ital.' ix. 105-110.
E. Wiedemann .	On a Means to Determine the Pressure at the Surface of the Sun and Stars, and some Spectroscopic Remarks. (Read June 12.)	'Proc. Phys. Soc.' iv. 31-34; 'Phil. Mag.' [5] x. 123-125; 'Beiblätter,' iv. 613 (Abs.)
L. Thollon . .	Observation d'une protubérance solaire le 30 août 1880. (Read Aug. 30.)	'C. R.' xci. 432-433; 'Beiblätter,' iv. 727 (Abs.)
Tacchini . . .	Observations des protubérances, des facules et des taches solaires pendant le premier semestre de l'année 1880. (Read Sept. 6.)	'C. R.' xci. 466-467.
E. C. Pickering .	New Planetary Nebulæ. (Sept. 7.)	'Am. J.' [3] xx. 303-305; 'Beiblätter,' v. 130 (Abs.)
L. Cruls . . .	Recherches spectroscopiques sur quelques étoiles non encore étudiées. (Read Sept. 13.)	'C. R.' xci. 486-487; 'Beiblätter,' v. 130-131 (Abs.)

ASTRONOMICAL APPLICATIONS, 1880, 1881.

L. Thollon . .	Sur quelques phénomènes solaires observés à Nice. (Read Sept. 13.)	'C. R.' xci. 487–492; 'Beiblätter,' v. 45 (Abs.)
" . .	Étude sur les raies telluriques du spectre solaire (Observatoire de Nice.) (Read Sept. 20.)	'C. R.' xci. 520–522; 'J. Chém. Sóc.' xl. 1 (Abs.); 'Beiblätter,' iv. 891–892 (Abs.)
E. Wiedemann .	On a Method of determining the Pressure on the Solar Surface.	'Monthly Not. Astr. Soc.' xl. 627–628.
C. A. Young . .	Spectroscopic Notes, 1879–1880. (Oct. 8.)	'Am. J.' [3] xx. 353–358; 'Beiblätter,' v. 127 (Abs.); 'Nature,' xxiii. 281.
W. H. M. Christie .	The Spectrum of Hartwig's Comet. (Oct. 11.)	'Nature,' xxii. 557; 'Beiblätter,' v. 129 (Abs.)
J. Macé and W. Nicati.	Étude de la distribution de la lumière dans le spectre solaire. (Read Oct. 11.)	'C. R.' xci. 623–625; 'Beiblätter,' v. 301–302 (Abs.)
L. Thollon . .	Études spectroscopiques faites sur le Soleil, à l'Observatoire de Paris. (Read Oct. 18.)	'C. R.' xci. 656–660; 'Beiblätter,' v. 45 (Abs.)
A. Serpieri . .	La Luce Zodiacale confronto tra le osservazioni del P. Dechevrens e quelle di G. Jones. (Oct. 1880.)	'Mem. Spettr. ital.' ix. 133–142.
A. Riccò . . .	Osservazioni solari dirette e spettroscopiche eseguite nel R. Osservatorio di Palermo nel III° trimestre, 1880.	'Mem. Spettr. ital.' ix. 161–189.
P. Tacchini . .	Macchie solari e facole osservate a Roma nei mesi di luglio, agosto e settembre.	'Mem. Spettr. ital.' ix. 190–192.
W. H. M. Christie .	On the Spectrum of Comet 1880 *d* (Hartwig's). (Nov. 10. Read Nov. 12.)	'Monthly Not. Astr. Soc.' xli. 52–53.
G. B. Airy . .	On the Spectrum of a Sun-Spot observed at the Royal Observatory, Greenwich, 1880. Nov. 27 and 30. (Dec. 7. Read Dec. 10.)	'Monthly Not. Astr. Soc.' xli. 63–64.
J. N. Lockyer . .	On a Sun-Spot observed Aug. 31, 1880. (Recd. Oct. 26. Read Nov. 25.)	'Proc. Roy. Soc.' xxxi. 72; 'Beiblätter,' v. 129 (Abs.)
Tacchini . . .	Observations solaires faites à l'observatoire royal du Collège romain pendant le troisième trimestre 1880. (Read Dec. 27.)	'C. R.' xci. 1053–1054.
" . . .	Osservazioni solari spettroscopiche e dirette fatte a Roma nel 3° trimestre del 1880.	Mem. Spettr. ital.' ix. 194–203.

1881.

Tacchini . . .	Macchie solari e facole osservate a Roma nei mesi di ottobre, novembre e dicembre del 1880.	'Mem. Spettr. ital.' x. 1–4.

ASTRONOMICAL APPLICATIONS, 1881.

C. S. Hastings . .	A Theory of the Constitution of the Sun, founded upon Spectroscopic Observations, original and other. (Sept. 1880.)	'Am. J.' [3] xxi. 33–44; 'Phil. Mag.' [5] xi. 91–103; 'Beiblätter,' v 588–592 (Abs.)
Tacchini . . .	Osservazioni solari dirette e spettroscopiche fatte a Roma nel 4° trimestre, 1880.	'Mem. Spettr. ital.' x. 5–11.
" . . .	Riassunto delle osservazioni 1880 .	'Mem. Spettr. ital.' x. 12.
C. A. Young . .	Spectroscopic Notes, 1879–1880. (Sept. 27, 1880.)	'Nature,' xxiii. 282.
G. B. Airy . .	Spectroscopic Results for the Motions of Stars in the Line of Sight, obtained at the Royal Observatory, Greenwich. IV. (Jan. 13. Read Jan. 14.)	'Monthly Not. Astr. Soc.' xli. 109–121.
J. N. Lockyer . .	On the Iron Lines widened in Solar Spots. (Recd. Jan. 13. Read Jan. 27.)	'Proc. Roy. Soc.' xxxi. 348–349; 'Beiblätter,' v. 288–289 (Abs.)
J. W. Draper . .	On the Phosphorograph of a Solar Spectrum, and on the Lines of its Infra-red Region. (Dec. 1, 1880.)	'Am. J.' [3] xxi. 171–182; 'Phil. Mag.' [5] xi. 157–169; 'Beiblätter,' v. 509–510 (Abs.)
Tacchini . . .	Observations des taches, des facules et des protubérances solaires, faites à l'observatoire du Collège romain, pendant le dernier trimestre, 1880. (Read March 7.)	'C. R.' xcii. 502–504.
A. Riccò . . .	Osservazioni solari eseguite nel R. Osservatorio di Palermo nel IV trimestre, 1880.	'Mem. Spettr. Ital.' x. 41–60.
J. N. Lockyer . .	Sur les raies du fer dans le Soleil. (Read April 11.)	'C. R.' xcii. 904–910; 'J. Chem. Soc.' xl. 669 (Abs)
W. de W. Abney .	On Lines in the Infra-red Region of the Solar Spectrum.	'Phil. Mag.' [5] xi. 300–301; 'Beiblätter,' v. 509–510 (Abs.)
E. C. Pickering .	Spectrum of the Star Ll. 13412. (April 14.)	'Nature,' xxiii. 604; 'Beiblätter,' v. 511 (Abs.)
J. N. Lockyer . .	Note on the Reduction of the Observations of the Spectra of 100 Sun-spots observed at Kensington. (Recd. May 12. Read May 12.)	'Proc. Roy. Soc.' xxxii. 203–206.
W. Huggins . .	Photographic Spectrum of the Comet. (June 27.)	'Nature,' xxiv. 200.
G. M. Seabroke .	The Spectrum of the Comet. (June 28.)	" xxiv. 201.
.	Spectrum of the Comet . . .	" xxiv. 224.
L. Thollon . .	Ditto	" xxiv. 224.
. .	The Comet	" xxiv. 261–262, 285–286.
J. N. Lockyer . .	Lectures on Solar Physics: The Chemistry of the Sun.	'Nature,' xxiv. 267–274, 296–301, 315–324, 365–370, 391–399.

ASTRONOMICAL APPLICATIONS, 1881—METEOROLOGICAL, 1870, 1871.

H. Draper . .	The Comet	'Nature,' xxiv. 308-309, 391-399.
W. Huggins . .	Preliminary Note on the Photographic Spectrum of Comet *b*, 1881. (Recd. June 27.)	'Proc. Roy. Soc.' xxxiii. 1-3.

METEOROLOGICAL.

1870.

'T. F.' . .	Spectrum of Aurora. (Oct. 25) . .	'Nature,' iii. 6.
T. G. Elger . .	Ditto. (Oct. 29) . .	,, iii. 6.
H. R. Procter . .	Ditto. (Oct. 27) . .	,, iii. 6-7.
J. R. Capron . .	Ditto. (Nov. 5) . .	,, iii. 28.
H. R. Procter . .	The Spectrum of the Aurora (Nov. 12.)	,, iii. 68.
E. C. Pickering .	Ditto . .	,, iii. 104-105.
J. Hyatt . . .	Ditto . .	,, iii. 105.
D. Kirkwood . .	Ditto. (Nov. 9) . .	,, iii. 126.
J. Browning . .	On the Spectrum of the Aurora Borealis.	'Monthly Not. Astr. Soc.' xxxi. 17; 'Phil. Mag.' [4] xli. 79; 'Am. J.' [3] i. 215.

1871.

H. R. Procter . .	The Spectrum of the Aurora (Feb. 7.)	'Nature,' iii. 346-347.
F. Zöllner . .	Ueber das Spectrum des Nordlichtes. (Read Oct 31, 1870.)	'Ber. d. K. sächs. Ges. d. Wiss.' xxii. 254-260; 'Ann. Phys. u. Chem.' cxli. 574-581; 'Phil. Mag.' [4] xli. 122-127; 'Am. J.' [3] i. 372-373 (Abs.)
H. R. Procter . .	The Spectrum of the Aurora . .	'Nature,' iii. 369.
,, . .	The Spectra of the Aurora and Corona. (March 28.)	,, iii. 468.
A. S. Herschel .	The Aurora Borealis. (April 10) .	,, iii. 486.
C. Piazzi Smyth .	Spectra of Aurora, Corona, and Zodiacal Light. (April 14.)	,, iii. 509-510.
T. W. Backhouse .	Spectrum of the Aurora (May 16) .	,, iv. 66.
R. J. Ellery	Ditto (May 19) .	,, iv. 280.
H. Vogel . . .	Das Spectrum des Nordlichts. (Aug. 1871.	'Astr. Nachr.' lxxviii. 247-248.
Lord Lindsay . .	The Aurora	'Nature,' iv. 347.
,, . .	Correction of Diagram . . .	,, iv. 366.
H. Vogel . . .	Ueber die Spectra der Blitze. (Sept. 11.)	'Ann. Phys. u. Chem.' cxliii. 653-654.
J. Janssen . .	Études sur les raies telluriques du spectre solaire.	'Ann. Chim. et Phys.' xxiii. 274-299.
G. F. Barker . .	Note on the Spectrum of the Aurora	'Am. J.' [3] ii. 465-468; 'J. Chem. Soc.' [2] x. 119 (Abs.)

METEOROLOGICAL, 1872.

1872.

A. Cornu	Sur le spectre de l'aurore boréale du 4 février. (Read Feb. 5.)	'C. R.' lxxiv. 390–391.
Prazmowski	Étude spectrale de la lumière de l'aurore boréale du 4 février. (Read Feb. 5.)	„ lxxiv. 391–392.
C. Piazzi Smyth	The Aurora Borealis of Feb. 4. (Feb. 5.)	'Nature,' v. 282–283.
G. M. Seabroke	Ditto. (Feb. 5)	„ v. 283.
R. J. Friswell	Ditto	„ v. 283.
J. P. Maclear	Ditto. (Feb. 5)	„ v. 283.
J. J. Murphy	Ditto. (Feb. 4)	„ v. 283.
J. R. Capron	Ditto. (Feb. 5)	„ v. 284–285.
H. Cooper Key	Ditto. (Feb. 6)	„ v. 302.
T. W. Webb	Ditto	„ v. 303.
S. J. Perry	Ditto	„ v. 303.
C. Piazzi Smyth	Reference Spectrum for the Chief Aurora Line. (Feb. 16.)	„ v. 324.
J. P. Maclear	On the Spectrum of the Atmosphere. (Feb. 5.)	„ v. 341–342.
L. Respighi	Observations of the Aurora Borealis of Feb. 4 and 5, 1872. ('Gazz. Ufficiale d. Regno d'Ital.') (Feb. 5.)	„ v. 511–512.
A. C. Twining	The Aurora of Feb. 4, 1872	'Am. J.' [3] iii. 273–281.
E. J. Stone	Ditto. (Feb. 19)	'Nature,' v. 443; 'Am. J.' [3] iii. 391–392
Tacchini	Sur l'aurore boréale du 4 février. (Read Feb. 19.)	'C. R.' lxxiv. 540–542.
H. Tarry	Sur l'origine des aurores polaires. (Read Feb. 19.)	„ lxxiv. 549–553.
A. Secchi	Sur l'aurore boréale du 4 février, observée à Rome, et sur quelques nouveaux résultats d'analyse spectrale. (Feb 9. Read Feb. 26.)	„ lxxiv. 583–588.
C. Piazzi Smyth	Sur la raie brillante de couleur jaune citron, dans le spectre des aurores boréales.	„ lxxiv. 597.
Salet	Spectrum des Nordlichts. (Chem. Soc. Paris, March 1.)	'Ber.' v. 222 (Abs.)
A. J. v. Oettingen	Das Nordlicht-Spectrum. (Feb. 12)	'Ann. Phys. u. Chem.' cxlvi. 284–287.
	Sur le spectre d'aurore boréale	'Ann. Chim. et Phys.' [4] xxvi. 269–273.
J. P. Joule	Spectrum of Lightning. (June 19)	'Nature,' vi. 161.
H. R. Procter	Ditto. (June 19)	„ vi. 161.
„	Ditto. (July 12)	„ vi. 220.
G. H. Pringle	Spectrum of Aurora. (June 23)	„ vi. 260.
J. P. Maclear	Ditto. (Aug. 11)	„ vi. 329.

METEOROLOGICAL, 1872–1874.

H. C. Vogel . .	Untersuchungen über das Spectrum des Nordlichts. (Read July 1.)	'Ber. K. sächs. Ges. d. Wiss.' xxiii. 285–299 'Ann. Phys. u. Chem.' cxlvi. 569–585; 'J. Chem. Soc.' [2] x. 1061 (Abs.); 'Am. J.' [3] iv. 487–488 (Abs.)
E. S. Holden . .	Spectrum of the Aurora. (Oct. 14)	'Am. J.' [3] iv. 423–424; 'Phil. Mag.' [4] xliv. 478–479.
,, . .	Spectrum of Lightning. (Oct. 9) .	'Am. J.' [3] iv. 474–475.
	1873.	
J. R. Capron . .	The Spectrum of the Aurora and of the Zodiacal Light (List of Authorities on the Subject). (Nov. 9, 1872.)	'Nature,' vii. 182–183.
,, . .	Aurora Spectrum. (Jan 10) . .	,, vii. 201.
G. F. Barker . .	On the Spectrum of the Aurora of Oct. 14, 1872. (Dec. 30, 1872.)	'Am. J.' [3] v. 81–84.
H. R. Procter . .	Aurora Spectra. (Jan. 18) . .	'Nature,' vii. 242.
H. A. Rowland .	On the Auroral Spectrum . .	'Am. J.' v. 320.
T. W. Backhouse .	Spectrum of Aurora . . .	'Nature,' vii. 463.
N. von Konkoly .	Spectroscopic Observations of Meteors at the O'Gyalla Observatory, Hungary. (Aug. 12.)	'Monthly Not. Astr. Soc.' xxxiii. 575–576.
,, .	On the Spectroscopic Observation of a Meteor. (Oct. 17.)	'Monthly Not. Astr. Soc.' xxxiv. 82–83.
A. S. Herschel . .	Spectra of Shooting Stars . .	'Nature,' ix. 142–143.
	1874.	
A. J. Ångström .	Ueber das Spektrum des Nordlichts	'Ann. Phys. u. Chem.' Jubelband, . 424–429; 'Arch. de Genève,' [2] l. 204–205 (Abs.)
J. Crocé-Spinelli and Sivel.	Ascension scientifique à grande hauteur, exécutée le 22 mars 1874. (Read April 6.)	'C. R.' lxxviii. 946–950; 'Am. J.' viii. 136 (Abs.)
J. Janssen . .	Remarques sur le spectre de la vapeur d'eau à l'occasion du voyage aérostatique de MM. Crocé-Spinelli et Sivel. (Read April 13.)	'C. R.' lxxviii. 995–998.
A. Secchi . .	Observations relatives à une communication de M. Crocé-Spinelli sur les bandes de la vapeur d'eau dans le spectre solaire. (Read April 20.)	,, lxxviii. 1080–1081.
T. Hoh . . .	Blitz-Spectra. (April 24) . .	'Ann. Phys. u. Chem.' clii. 173–175.
S. Lemström . .	Sur la décharge électrique dans l'aurore boréale et le spectre du même phénomène.	'Arch. de Genève,' [2] l. 225–242, 355–386.
A. Wijkander . .	Observations sur le spectre de l'aurore boréale.	'Arch. de Genève,' [2] li. 25–30.

METEOROLOGICAL, 1874–1879.

J. W. Clark	Observations on the Spectrum of Lightning.	'Chem. News,' xxx. 28.
A. J. Ångström	The Spectrum of the Aurora Borealis	'Nature,' x. 210–211.
W. de Fonvielle	Note sur des observations spectroscopiques, faites dans l'ascension du 24 sept. 1874, pour étudier les variations des couleurs du spectre. (Read Oct. 5.)	'C. R.' lxxxix. 816–817.

1875.

A. S. Herschel	On the Spectrum of the Aurora	'Phil. Mag.' [4] xlix. 65–71.
J. B. N. Hennessey	On the Atmospheric Lines of the Solar Spectrum, illustrated by a Map drawn on the same Scale as that adopted by Kirchhoff. (Map recd. June 9, 1874; text, Jan. 11, 1875. Read Jan. 28.)	'Phil. Trans.' 1875, clxv. 157–160; 'Proc. Roy. Soc.' xxiii. 201–202; (Abs.); 'Am. J.' [3] ix. 307 (Abs.)
J. R. Capron	On the Comparison of some Tube and other Spectra with the Spectrum of the Aurora.	'Phil. Mag.' [4] xlix. 249–266.
W. M. Watts	On the Spectrum of the Aurora. (April 14.)	'Phil. Mag.' [4] xlix. 410–411.
Piazzi Smyth	Spectroscopic Prevision of Rain with a High Barometer. (July 19 and 26.)	'Nature,' xii. 231–232 and 252–253; 'Ann. Phys. u. Chem.' clvii. 175–176 (Abs.)
C. Michie Smith	The Spectroscope and the Weather. (Aug. 13.)	'Nature,' xii. 366.
J. W. Clark	Some further Observations on the Spectra of Lightning.	'Chem. News,' xxxii. 65.
J. R. Capron	On the Spectrum of the Aurora	'Phil. Mag.' [4] xlix. 481.
A. Crova	Sur l'intensité calorifique de la radiation solaire et son absorption par l'atmosphère terrestre. (Read Dec. 13.)	'C. R.' lxxxi. 1205–1207.

1876.

Piazzi Smyth	The Warm Rain Band in the Daylight Spectrum. (April 24.)	'Nature,' xiv. 9.

1877.

J. W. Clark	On the Spectra of Lightning	'Chem. News,' xxxv. 2; 'Beiblätter,' i. 192.
J. P. Maclear	Spectrum of Aurora Australis	'Nature,' xvii. 11–12.
H. C. Russell	On the Atmospheric Lines between the two D Lines. (July 26. Read Nov. 9.)	'Monthly Not. Astr. Soc.' xxxviii. 30–32.

1879.

A. Schuster	On Spectra of Lightning. (Read Feb. 22.)	'Proc. Phys. Soc.' iii. 46–52; 'Phil. Mag.' [5] vii. 316–321; 'Beiblätter,' iii. 872 (Abs.)

METEOROLOGICAL, 1879, 1880—CHEMICAL RELATIONS, 1870, 1871.

Piazzi Smyth . .	Ueber meteorologische Spectroskopie.	'Zeitschr. d. österr. Ges. für Meteorologie,' xiv. 151–152.
Von Konkoly . .	Spectroscopische Beobachtungen der Meteorite. (Aug. 15.)	'Astron. Nachr.' xcv. 283–286; 'Nature,' xx. 521–522 (Abs.)

1880.

L. Thollon . .	Étude sur les raies telluriques du spectre solaire. (Observatoire de Nice.) (Read Sept. 20.)	'C. R.' xci. 520–522; 'J. Chem. Soc.' xl. 1 (Abs.); 'Beiblätter,' iv. 891–892 (Abs.)
R. Copeland . .	Observations of Aurora on Aug. 12 and 13.	'Nature,' xxii. 510.
E. Lecher . .	Ueber die Absorption der Sonnenstrahlung durch die Kohlensäure unserer Atmosphäre. (Read Nov. 4.)	'Sitzungsb. Wien. Akad.' lxxxii. II. 851–863; 'Wien. Anz. xvii. 217–218 (Abs.)

CHEMICAL RELATIONS.

1870.

W. H. Perkin . .	On Artificial Alizarin . . .	'Journ. Chem. Soc.' [2] viii. 133–143; 'Ann. Chem. u. Pharm.' clviii. 315–319 (Abs.); 'Ann. Chim. et Phys.' [4] xxvi. 136–137 (Abs.)
H. C. Sorby . .	On some Technical Applications of the Spectrum Microscope.	'Quart. J. Microsc. Sci.' 1869, ix. 358–383; 'Dingl. J.' cxcviii. 243–254, 334–348.
,, . .	On the Colouring Matters derived from the Decomposition of some Minute Organisms. (Read April 13.)	'Monthly Mic. J.' iii. 229–231.
L. Schönn . .	Ueber Blattgrün und Blumenblau. (May 10.)	'Zeitschr. anal. Chem.' ix. 327–328.
J. M. Silliman . .	On the Examination of the Bessemer Flame with Colored Glasses and with the Spectroscope.	'Am. J.' [2] l. 297–307; 'Phil. Mag.' xli. 1–12; 'J. Chem. Soc.' [2] ix. 97–98 (Abs.)
H. C. Sorby . .	On some Compounds derived from the Colouring Matter of Blood.	'Quart. J. Mic. Sci.' x. 400–402.

1871.

J. S. Parker . .	On the Examination of the Bessemer Flame with Coloured Glasses and with the Spectroscope.	'Chem. News,' [2] xxiii. 25–26; 'J. Chem. Soc.' [2] ix. 98 (Abs.)
H. C. Sorby . .	On some Improvements in the Spectrum Method of Detecting Blood.	'Monthly Mic. J.' vi. 9–17.
F. Mohr . . .	Uber die Beziehung der chemischen Beschaffenheit zu der lichtbrechenden Kraft der Gase.	'Ber.' iv. 149–155; 'J. Chem. Soc.' [2] ix. 183 (Abs.)

CHEMICAL RELATIONS, 1871.

C. Schultz-Sellack .	Ueber die Lichtempfindlichkeit der Silberhaloïdsalze und den Zusammenhang von optischer und chemischer Lichtabsorption.	'Ann. Phys. u. Chem.' cxliii. 161–171; 'Ber.' iv. 210–211 (Abs.); 'J. Chem. Soc.' [2] ix. 302–303 (Abs.); 'Phil. Mag.' [4] xli. 549–550 (Abs); 'Ann. Chim. et Phys.' [4] xxvi. 280 (Abs.)
K. Vierordt . .	Ueber die Anwendung des Spectral-Apparates zur quantitativen Bestimmung von Farbstoffen. (Read Mar. 27.)	'Ber.' iv. 327–329; 'J. Chem. Soc.' [2] ix. 602 (Abs.); 'Phil. Mag.' [4] xli. 482–484; 'Am. J.' ii. 138–139 (Abs.)
H. C. Sorby . .	On the Colour of Leaves at different Seasons of the Year.	'Quart. J. Mic. Sci.' xi. 215–234.
W. Wernicke . .	Ueber die Brechung und Dispersion des Lichtes in Iod-, Brom- und Chlorsilber. (Dec. 1870.)	'Ann. Phys. u. Chem.' cxlii. 560–573; 'J. Chem. Soc.' [2] ix. 653–654 (Abs.); 'Ann. Chim. et Phys.' [4] xxvi. 287–288 (Abs.)
H. C. Sorby . .	On the various Tints of Autumnal Foliage.	'Chem. News,' xxiii. 137–139, 148–150; 'J. Chem. Soc.' [2] ix. 184–185 (Abs.)
W. Preyer . .	Quantitative Spectralanalyse. (May 2.)	'Ber.' iv. 404.
H. E. Roscoe . .	Employment of Spectrum Analysis in the Bessemer Process.	'J. Iron and Steel Inst.' 1871, ii. 38–62; 'Ber.' iv. 419–421 (Abs.)
K. Vierordt . .	Zur quantitativen Spectralanalyse. (May 11.)	'Ber.' iv. 457.
H. Schiff . . .	Ueber die quantitative Bestimmung von Farbstoffen mittelst des Spektroskops. (May 15.)	'Ber.' iv. 474–475; 'J. Chem. Soc.' [2] ix. 760 (Abs.)
K. Vierordt . .	Zur quantitativen Spectralanalyse. (May 25. Recd. June 1.)	'Ber.' iv. 519; 'J. Chem. Soc.' [2] ix. 759–760 (Abs.)
H. C. Sorby . .	On the Colouring Matter of some Aphides.	'Quart. J. Mic. Sci.' xi. 352–361.
E. Gerland and N. W. H. Rauwenhoff.	Recherches sur la chlorophylle et quelques-uns de ses dérivés. (Feb. 1871.)	'Arch. Néerlandaises,' vi. 97–116; 'Ann. Phys. u. Chem.' cxliii. 231–239; 'J. Chem. Soo'. [2] ix. 1201–1202 (Abs.)
J. L. Sirks . .	Ueber die Refraction und Dispersion des Selens. (June 1871.)	'Ann. Phys. u. Chem.' cxliii. 429–439; 'Ann. Chim. et Phys.' [4] xxvi. 286–287 (Abs.)
E. Lommel . .	Ueber das Verhalten des Chlorophylls zum Licht.	'Ann. Phys. u. Chem.' cxliii. 568–585; 'J. Chem. Soc.' [2] x. 158–160 (Abs.)

CHEMICAL RELATIONS, 1871, 1872.

E. Gerland . .	Ueber die Einwirkung des Lichtes auf das Chlorophyll. (June 1871.)	'Ann. Phys. u. Chem.' cxliii. 585–610; 'J. Chem. Soc.' [2] x. 160–164 (Abs.)
F. Papillon . .	Sur les rapports des propriétés spectrales des corps simples avec leurs propriétés physiologiques. (Read Sept. 25.)	'C. R.' lxxiii. 791–792; 'J. Chem. Soc.' [2] ix. 1078 (Abs.)
H. C. Sorby . .	On the Examination of Mixed Colouring Matters with the Spectrum Microscope.	'Monthly Mic. J.' vi. 124–134.
G. Salet . . .	Sur les spectres de l'étain et de ses composés. (Read Oct. 2.)	'C. R.' lxxiii. 862–863; 'J. Chem. Soc.' [2] ix. 1147–1149 (Abs.)
R. Blochman . .	Ueber das Calciumspectrum . .	'J. pr. Chem.' [2] iv. 282–286; 'J. Chem. Soc.' [2] ix. 1149–1150 (Abs.)
R. Boettger and T. Petersen.	Notiz über künstliches Alizarin. (Oct. 6. Read Oct. 9.)	'Ber.' iv. 778–779.
A. Heynsius and G. F. F. Campbell.	Die Oxydationsproducte der Gallenfarbstoffe und ihre Absorptionsstreifen.	'Pflüger's Archiv f. Physiol.' iv. 497–547; 'J. Chem. Soc.' [2] x. 307–308 (Abs.)
G. Salet . . .	Sur les spectres du phosphore et des composés du silicium. (Read Oct. 30.)	'C. R.' lxxiii. 1056–1059; 'J. Chem. Soc.' [2] x. 27 (Abs.)
P. Bert . . .	Influence des diverses couleurs sur la végétation. (Read Dec. 18.)	'C. R.' lxxiii. 1444–1447.

1872.

K. Vierordt . .	Zur quantitativen Spectralanalyse. (Jan. 2. Read Jan. 22.)	'Ber.' v. 34–38.
E. Lommel . .	Zur Frage über die Wirkung des farbigen Lichtes auf die Assimilationsthätigkeit der Pflanzen. (Dec. 1871.)	'Ann. Phys. u. Chem.' cxlv. 442–455; 'J. Chem. Soc.' [2] xi. 292–293 (Abs.)
R. Maly . . .	Künstliche Umwandlung von Bilirubin in Harnfarbstoff.	'Ann. Chem. u. Pharm.' clxi. 368–370; 'J. Chem. Soc.' [2] x. 514 (Abs.)
C. Horner . .	The Spectra of Manganese in Blowpipe Beads.	'Chem. News,' xxv. 139; 'J. Chem. Soc.' [2] x. 524 (Abs.)
R. Maly . . .	Untersuchungen über die Gallenfarbstoffe.	'Wien. Anz.' ix. 39–41; 'Chem. Centr.' [3] iii. 180–181; 'J. Chem. Soc.' [2] x. 638 (Abs.)
" . . .	Umwandlung von Bilirubin in Harnfarbstoff. (Feb. 1872.)	'Ann. Chem. u. Pharm.' clxiii. 77–95; 'J. Chem. Soc.' [2] x. 835 (Abs.)
P. Blaserna . .	Misura dell' indice di rifrazione dell' alcool anisico e dell' alcool metilsalicilico.	'Gazz. Chim. Ital.' ii. 69–75.
T. A. Hartsen . .	Purpurophyll, ein neues (?) Derivat des Chlorophylls.	'Ann. Phys. u. Chem.' cxlvi. 158–160.

CHEMICAL RELATIONS, 1872, 1873.

B. J. Stokvis . .	Untersuchungen über die Gallenfarbstoffe und ihre Erkennung mittelst des Spectroskops.	'Ber.' v. 583–585; 'J. Chem. Soc.' [2] xi. 78 (Abs.)
R. Landolt . .	Refractions-Aequivalente der Elemente C, H und O (Versammlung Deutschen Naturf. u. Aerzte, Aug. 12–18.)	'Ber.' v. 808; 'Chem. Centr.' [3] iii. 705; 'J. Chem. Soc.' [2] xi. 460 (Abs.)
W. Pfeffer . .	Die Wirkung der Spectralfarben auf die Kohlensäurezersetzung in Pflanzen.	'Versuchs-Stationen-Organ,' xv. 356–367; 'J. Chem. Soc.' [2] x. 1107 (Abs.)
J. Dewar. . .	On the Chemical Efficiency of Sunlight. ('Roy. Soc. Edin.' May 6.)	'Phil. Mag.' [4] xliv. 307–311.
	Propriétés optiques de la chlorophylle.	'Ann. Chim. et Phys.' [4] xxvi. 277–279.
J. W. Draper . .	Researches in Actino-chemistry. Memoir Second. On the Distribution of Chemical Force in the Spectrum.	'Phil. Mag.' [4] xliv. 422–443; 'Am. J.' v. 25–38, 91–98; 'J. Chem. Soc.' [2] xi. 232–235 (Abs.)
K. B. Hofmann .	Ueber die Spectral-Erscheinungen des Phosphorwasserstoffs und des Ammoniaks.	'Ann. Phys. u. Chem.' cxlvii. 92–101; 'J. Chem. Soc.' [2] xi. 340–341 (Abs.)
P. T. Clève and O. Hœglund.	Sur les combinaisons de l'yttrium et de l'erbium.	'Bull. Soc. Chim. Paris,' xviii. 193–201, 289–297; 'J. Chem. Soc.' [2] xi. 136–139 (Abs.)
B. J. Stokvis . .	Oxidation Product of Bile Pigment ('N. Repert. Pharm.' xxi. 732–737.)	'J. Chem. Soc.' [2] xi. 288 (Abs.)
E. Wiedemann .	Ueber die Brechungsexponenten der geschwefelten Substitutionsproducte des Kohlensäuresäthers.	'J. pr. Chem.' [2] vi. 453–455.

1873.

J. Chautard . .	Examen spectroscopique de la chlorophylle dans les résidus de la digestion. (Read Jan. 13.)	'C. R.' lxxvi. 103–105; 'J. Chem. Soc.' [2] xi. 521 (Abs.)
A. Millardet . .	Observations relatives à une communication récente de M. Chautard sur les bandes d'absorption de la chlorophylle. (Read Jan. 13.)	'C. R.' lxxvi. 105–107 (Abs.); 'J. Chem. Soc.' [2] xi. 996 (Abs.)
W. Pfeffer . .	Die Wirkung der Spectralfarben auf die Kohlensäurezersetzung in Pflanzen ('Sitzungsb. d. Ges. z. Beförderung d. Gesammt. Naturwiss. zu Marburg').	'Ann. Phys. u. Chem.' cxlviii. 86–99; 'J. Chem. Soc.' [2] xi. 400–401 (Abs.) 'Chem. News,' xxvii. 133–134 (Abs.)
E. Gerland . .	Ueber die Rolle des Chlorophylls bei der Assimilationsthätigkeit der Pflanzen und das Spectrum der Blätter. (July 1872.)	'Ann. Phys. u. Chem.' cxlviii. 99–115; 'J. Chem. Soc.' [2] xi. 401 (Abs.)
H. Vogel . .	Ueber die Lichtempfindlichkeit der Silberhaloïdsalze unter alkalischer Entwickelung. (Read Jan. 15.)	'Ber.' vi. 88–92.

CHEMICAL RELATIONS, 1873.

L. d'Henry . .	Sur l'emploi de la lumière monochromatique, produite par les sels de soude, pour apprécier les changements de couleur de la teinture de tournesol, dans les essais alkalimétriques. (Read Jan. 27.)	'C. R.' lxxvi. 222–224 (Abs.); 'Ann. Chem. u. Pharm.' clxix. 272; 'Dingl. J.' ccvii. 405–407.
C. A. Valson . .	Propriétés modulaires des pouvoirs réfringents dans les solutions salines. (Read Jan. 27.)	'C. R.' lxxvi. 224–226; 'J. Chem. Soc.' [2] xi. 460–461 (Abs.)
W. M. Watts . .	On the Spectrum of the Bessemer Flame.	'Phil. Mag.' [4] xlv. 81–90; 'J. Chem. Soc.' [2] xi. 461 (Abs.)
M. Th. Edelmann .	Ueber eine neue Methode der objectiven Darstellung von Metallspectren.	'Chem. Centr.' 1872, 691; 'J. Chem. Soc.' [2] xi. 461 (Abs.)
J. Chautard . .	Modifications du spectre de la chlorophylle sous l'influence des alcalis. (Read Mar. 3.)	'C. R.' lxxvi. 570–572; 'J. Chem. Soc.' [2] xi. 582 (Abs.)
P. Champion, H. Pellet, and M. Grenier.	De la Spectrométrie; spectronatromètre. (Read Mar. 17.)	'C. R.' lxxvi. 707–711; 'J. Chem. Soc.' [2] xi. 934–935 (Abs.)
J. Janssen . .	Note sur l'analyse spectrale quantitative, à propos de la Communication précédente de MM. Champion, Pellet et Grenier. (Read Mar. 17.)	'C. R.' lxxvi. 711–713; 'J. Chem. Soc.' [2] xi. 1258 (Abs.)
F. Grimm . .	Ueber das Phthaleïn des Hydrochinons und Chinizarin. (Read Mar. 24.)	'Ber.' vi. 506–512.
Lecoq de Boisbaudran.	Sur le spectre de l'acide borique. (Mar. 23. Read Mar. 31.)	'C. R.' lxxvi. 833–835.
J. Chautard . .	Influence des rayons de diverses couleurs sur le spectre de la chlorophylle. (Read April 21.)	'C. R.' lxxvi. 1031–1033; 'J. Chem. Soc.' [2] xi. 713 (Abs.)
" . .	Examen des différences présentées par le spectre de la chlorophylle selon la nature du dissolvant. (Read April 28.)	'C. R.' lxxvi. 1066–1069; 'J. Chem. Soc.' [2] xi. 996–997.
Le Neve Foster .	Prüfung des gelben Glases für Dunkelzimmer der Photographen.	'Dingl. J.' ccvii. 427; 'J. Chem. Soc.' [2] xi. 948 (Abs.)
C. Horner . .	On the Spectra of some Cobalt Compounds in Blowpipe Chemistry.	'Chem. News,' xxvii. 241–242; 'J. Chem. Soc.' [2] xi. 1161–1162 (Abs.)
H. W. Vogel . .	Ueber die fortsetzenden Strahlen Becquerel's. (Read June 9.)	'Ber.' vi. 1498–1501.
Is. Pierre and E. Puchot.	Comparaison des indices de réfraction dans quelques éthers composés isomères. (Read June 30.)	'C. R.' lxxvi. 1566–1568.
J. B. Hannay . .	On Zirconia	'J. Chem. Soc.' [2] xi. 703–710; 'Ber.' vi. 571 (Abs.)
R. Hennig . .	Ueber quantitative Analyse durch Spectralbeobachtung. (Mar. 20.)	'Ann. Phys. u. Chem.' cxlix. 349–353; 'J. Chem. Soc.' [2] xii. 495 (Abs.)

CHEMICAL RELATIONS, 1873, 1874.

H. Pocklington .	M. Chautard's Classification of the Absorption Bands of Chlorophyll.	'Pharm. J. Trans.' [3] iv. 61–63.
K. Timiraeseff .	Die Zersetzung der CO_2 durch die Pflanzen im directen Sonnenspectrum. (S. Petersburg, Sept.)	'Ber.' vi. 1212 (Abs.); 'J. Chem. Soc.' [2] xii. 285 (Abs.)
R. Thalén . .	Om Spektra tillhörande yttrium, erbium, didym och lanthan. (Sept. 9.)	'K. Svensk. Vetenskaps Akad. Förhandlingar.' xii. No. 4, 24 pp.; 'Bull. Soc. Chim.' [2] xxii. 350 (Abs.)
H. Vogel . .	Ueber die Lichtempfindlichkeit des Bromsilbers für die sogenannten chemisch unwirksamen Farben. (Oct. 1873. Read Nov. 10.)	'Ber.' vi. 1302–1306; 'Ann. Phys. u. Chem.' cl. 453–459; 'J. Chem. Soc.' [2] xii. 217 (Abs.); 'Am. J.' [3] vii. 140–141; 'Phil. Mag.' [4] xlvii. 273–277.
Lecoq de Boisbaudran.	Sur quelques spectres métalliques (plomb, chlorure d'or, thallium, lithium.) (Read Nov. 17.)	'C. R.' lxxvii. 1152–1154; 'J. Chem. Soc.' [2] xii. 217 (Abs.); 'Ber.' vi. 1418 (Abs.)
J. N. Lockyer and W. C. Roberts.	On the Quantitative Analysis of certain Alloys by means of the Spectroscope. (Recd. Nov. 20. Read Nov. 27.)	'Phil. Trans.' 1874, clxiv. 495–499; 'Proc. Roy. Soc.' xxi. 507–508 (Abs.); 'Ber.' vi. 1426 (Abs.); 'J. Chem. Soc.' [2] xii. 495 (Abs.); 'Phil. Mag.' [4] xlvii. 311–312 (Abs.)
J. N. Lockyer . .	Note préliminaire sur les éléments existant dans le Soleil. (Read Dec. 8.)	'C. R.' lxxvii. 1347–1352; 'Ber.' vi. 1554–1555 (Abs.); 'J. Chem. Soc.' [2] xii. 424–426 (Abs.)
Berthelot . .	Sur la nature des éléments chimiques. Observations à propos de la communication de M. Lockyer. (Read Dec. 8.)	'C. R.' lxxvii. 1352–1357; 'J. Chem. Soc.' [2] xii. 426–427 (Abs.)
,, . .	Nouvelles remarques sur la nature des éléments chimiques. (Read Dec. 15.)	'C. R.' lxxvii. 1399–1403.

1874.

H. Vogel . . .	Ueber die Schwankungen in der chemischen Wirkung des Sonnenspektrums und über einen Apparat zur Messung derselben. (Jan. 5. Read Jan. 12.)	'Ber.' vii. 88–92; 'J. Chem. Soc.' [2] xii. 424 (Abs.); 'Am. J.' [3] vii. 414–415 (Abs.)
C. Horner . .	On the Spectra of Boric and Phosphoric Acid Blowpipe Beads.	'Chem. News,' xxix. 66–68; 'J. Chem. Soc.' [2] xii. 642–643 (Abs.)
W. Stein . . .	Zur Spectralanalyse gefärbter Flüssigkeiten und Gläser.	'J. pr. Chem.' ix. 383–384; 'J. Chem. Soc.' [2] xiii. 412–414 (Abs.)
J. Chautard . .	Nouvelles bandes surnuméraires produites dans les solutions de chlorophylle, sous l'influence d'agents sulfurés. (Read Feb. 9.)	'C. R.' lxxviii. 414–416; 'J. Chem. Soc.' [2] xii. 643–644 (Abs.)

CHEMICAL RELATIONS, 1874.

E. Becquerel . .	Observations sur un mémoire de M. E. Marchand relatif à la mesure de la force chimique contenu dans la lumière du soleil.	'Ann. Chim. et Phys.' [4] xxx. 572–573; 'J. Chem. Soc.' [2] xii. 942–943 (Abs.)
W. N. Hartley .	Preliminary Notice of Experiments concerning the Chemical Constitution of Saline Solutions. (Recd. Feb. 3. Read March 19.)	'Proc. Roy. Soc.' xxii. 241–243; 'Chem. News,' xxix. 148.
J. Wiesner . .	Welche Strahlen des Lichtes zerlegen bei Sauerstoffzutritt das Chlorophyll? (March 1874.)	'Ann. Phys. u. Chem.' clii. 496–503; 'Chem. Centr.-Blatt.' [3] v. 353–354 (Abs.); 'J. Chem. Soc.' [2] xii. 999 (Abs.)
H. Vogel . . .	Ueber die chemische Wirkung des Sonnenspectrums auf Silberhaloïdsalze. (Read April 13.)	'Ber.' vii. 545–550; 'J. Chem. Soc.' [2] xii. 756 (Abs.)
P. Truchot . .	De la présence de la lithine dans le sol de la Limagne et dans les eaux minérales d'Auvergne. Dosage de cet alcali au moyen du spectroscope. (Read April 13.)	'C. R.' lxxviii. 1022–1024; 'Ber.' vii. 653 (Abs.)
M. Carey Lea . .	On the Influence of Color upon Reduction by Light.	'Am. J.' [3] vii. 200–207.
H. Vogel . . .	Ueber die Beziehung zwischen chemischer Wirkung des Sonnenspektrums, der Absorption und anomalen Dispersion. (Read July 13.)	'Ber.' vii. 976–979; 'J. Chem. Soc.' [2] xii. 1121–1122.
E. Becquerel . .	Action des rayons différemment réfrangible sur l'iodure et le bromure d'argent; influence des matières colorantes. (Read July 27.)	'C. R.' lxxix. 185–190; 'J. Chem. Soc.' [2] xiii. 30 (Abs.)
J. W. Draper . .	Early Contributions to Spectrum Photography and Photo-Chemistry. (July 8.)	'Nature,' x. 243–244.
H. W. Vogel . .	Ueber die chemische Wirkung des Sonnenspectrums auf Silberhaloïdsalze. (Aug. 1874.)	'Ann. Phys. u. Chem.' cliii. 218–250; 'J. Chem. Soc.' [2] xiii. 326 (Abs.)
F. Filhol . . .	Note sur la chlorophylle. (Read Sept. 7.)	'C. R.' lxxix. 612–614; 'J. Pharm. et Chim.' [4] xx. 345–347; 'J. Chem. Soc.' [2] xiii. 371–372 (Abs.)
Pringsheim . .	Ueber die Absorptionsspectra der Chlorophyllfarbstoffe. (Read Oct. 22.)	'Monatsb. Berl. Akad.' 1874, 628–659.
J. Wiesner . .	Notiz über die Strahlen des Lichtes, welche das Xantophyll der Pflanze zerlegen. (Nov. 1874.)	'Ann. Phys. u. Chem.' cliii. 622–623.
A. Adamkiewicz .	Farbenreactionen des Albumin. (Mar. 1874.)	'Pflüger's Archiv f. Physiol.' ix. 156–162; 'J. Chem. Soc.' [2] xiii. 172 (Abs.)

CHEMICAL RELATIONS, 1874, 1875.

F. Baumstark . .	Zwei pathologische Harnfarbstoffe .	'Pflüger's Archiv f. Physiol.' ix. 568–584; 'J. Chem. Soc.' [2] xiii. 480 (Abs.)
W. Stein . . .	Zur Spectralanalyse gefärbter Flüssigkeiten, Gläser und Dämpfe.	'J. pr. Chem.' x. 368–384; 'J. Chem. Soc.' [2] xiii. 412–414 (Abs.)

1875.

Vogel . . .	Ueber die Beziehungen zwischen Lichtabsorption und Chemismus. (Read Jan. 21.)	'Monatsb. Berl. Akad.' 1875, 82–83.
H. W. Vogel . .	Ueber abnorme Wirkung mancher Farbstoffe auf die Lichtempfindlichkeit photographischer Platten. (Read Jan. 25.)	'Ber.' viii. 95–96.
" . .	Ueber das Spectrum der Sell'schen Schwefelkohlenstofflampe. (Read Jan. 25.)	" viii. 96–98.
A. Riche and C. Bardy.	De la flamme du soufre et des diverses lumières utilisables en photographie. (Read Jan. 25.)	'C. R.' lxxx. 238–241; 'Ber.' viii. 182–183 (Abs.)
H. C. Sorby . .	On the Chromatological Relations of Spongilla fluviatilis.	'Quart. J. Mic. Sci.' xv. 47–52.
" . .	On the Colouring Matter of Bonellia viridis.	'Quart. J. Mic. Sci.' xv. 166–172.
M. Carey Lea . .	On the Action of the Less Refrangible Rays of Light on Silver Iodide and Bromide. (Mar. 6.)	'Am. J.' [3] ix. 269–278; 'J. Chem. Soc.' 1876, i. 28 (Abs.)
A. W. Wright . .	Spectroscopic Examination of Gases from Meteoric Iron. (Mar. 18.)	'Am. J.' [3] ix. 294–302; 'J. Chem. Soc.' 1876, i. 27–28 (Abs.)
J. L. W. Thudichum	Further Researches on Bilirubin and its Compounds.	'J. Chem. Soc.' [2] xiii. 389–403.
K. Vierordt . .	Die Anwendung der quantitativen Spectralanalyse bei den Titrirmethoden. (March 1875.)	'Ann. d. Chem.' clxxvii. 31–45; 'Am. J.' [3] x. 216–217 (Abs.)
H. Ballmann . .	Ueber quantitative Bestimmung des Lithiums mit dem Spectral-Apparat. (April 15.)	'Zeitschr. Anal. Chem.' xiv. 297–301; 'J. Chem. Soc.' 1876, ii. 550 (Abs.)
Sir J. G. N. Alleyne	On the Estimation of Small Quantities of Phosphorus in Iron and Steel by Spectrum Analysis. (Read May 6.)	'J. Iron and Steel Inst. 1875, 62–72.
A. W. Wright . .	Preliminary Note on an Examination of Gases of the Meteorite of Feb. 12. (May 22.)	'Am. J.' [3] ix. 459–460; 'J. Chem. Soc.' 1876, i. 352 (Abs.)
H. Bührig . .	Das Absorptionsspectrum des Didyms. (May 1875.)	'J. pr. Chem.' [2] xii. 209–215; 'Am. J.' [3] xi. 142 (Abs.)
H. W. Vogel . .	Photographische Spectralbeobachtungen im Rothen und Indischen Meere. (July 1875.)	'Ann. Phys. u. Chem. clvi. 319–325.

Chemical Relations, 1875.

R. Weber . .	Ueber den Einfluss farbigen Lichtes auf die Assimilation und die damit zusammenhängende Vermehrung der Aschenbestandtheile in Erbsen-Keimlingen.	'Landw. Versuchs-Stat.' xviii. 18–48; 'J. Chem. Soc.' [2] xiii. 1211–1215 (Abs.)
L. Liebermann .	Ueber Choletelin und Hydrobilirubin	'Pflüger's Arch. f. Physiol.' xi. 181–190; 'J. Chem. Soc.' 1876, i. 407–408 (Abs.)
A. Greiner . .	Ueber phosphorhaltigen Stahl .	'Dingl. J.' ccxvii. 33–41; 'J. Chem. Soc.' 1876, i. 454–457 (Abs.)
Lecoq de Boisbaudran	Caractères chimiques et spectroscopiques d'un nouveau métal, le gallium, découvert dans une blende de la mine de Pierrefitte, vallée d'Argelès (Pyrénées). (Read Sept. 20.)	'C. R.' lxxxi. 493–495; 'Phil. Mag.' [4] l. 414–416; 'J. Chem. Soc.' 1876, i. 190 (Abs.); 'Am. J.' [3] xi. 320 (Abs.)
C. Graebe and H. Caro.	Ueber Rosolsäure. (Sept. 28) .	'Ann. d. Chem.' clxxix. 184–203; 'J. Chem. Soc.' 1876, i. 588–591.
H. W. Vogel . .	Ueber die Absorptionsspectra verschiedener Farbstoffe, sowie über die Anwendung derselben zur Entdeckung von Verfälschungen. (Sept. 17. Read Oct. 11.)	'Ber.' viii. 1246–1254; 'Dingl. J.' ccxix. 73–81.
A. and G. de Negri .	Nuovo metodo spettroscopico per discoprire nei miscugli gassosi e nelle acque le più piccole quantità d'un idrocarburo gassoso od almeno molto volatile. (Oct. 11.)	'Gazz. Chim. Ital.' v. 438; 'J. Chem. Soc.' 1876, ii. 659 (Abs.)
S. L. Schenk . .	Der grüne Farbstoff von Bonellia viridis. (Read Oct. 28.)	'Sitzungsb. Wien. Akad.' lxxii. II. 581–585.
T. L. Phipson . .	On Noctilucine, the Phosphorescent Principle of Luminous Animals.	'Chem. News,' xxxii. 220; 'J. Chem. Soc.' 1876, i. 720 (Abs.)
L. Liebermann .	Untersuchungen über das Chlorophyll, den Blumenfarbstoff und deren Beziehungen zum Blutfarbstoffe. (Read Nov. 18.)	'Sitzungsb. Wien. Akad.' lxxii. II. 599–618; 'Chem. Centr.' [3] vii. 615–616; 'J. Chem. Soc.' 1877, ii. 208 (Abs.)
H. W. Vogel . .	Ueber die Absorptionsspectren einiger Salze der Metalle der Eisengruppe und ihre Anwendung in der Analyse. (Read Nov. 22.)	'Ber.' viii. 1533–1540.
Pringsheim . .	Ueber natürliche Chlorophyllmodificationen und die Farbstoffe der Florideen. (Read Dec. 2.)	'Monatsb. Berl. Akad.' 1875, 745–749.
Lecoq de Boisbaudran	Sur quelques propriétés du gallium. (Read Dec. 6.)	'C. R.' lxxxi. 1100–1105; 'Am. J.' [3] xi. 320 (Abs.); 'Phil. Mag.' [5] i. 173–176.
H. W. Vogel . .	Ueber die chemische Wirkung des Lichts auf reines und gefärbtes Bromsilber. (Recd. Dec. 15.)	'Ber.' viii. 1635–1636; 'J. Chem. Soc.' 1876, i. 510 (Abs.); 'Am. J.' [3] xi. 215–216 (Abs.)

CHEMICAL RELATIONS, 1875, 1876.

R. Sachsse	Ueber die Bedeutung des Chlorophylls. (Read Dec. 17.)	'Sitzungsb. Naturf.-Ges. zu Leipzig.' ii. 155–120; 'Chem. Centr.' [3] vii. 550–552; 'J. Chem. Soc.' 1877, ii. 208–209 (Abs.)

1876.

J. Waterhouse	On Reversed Photographs of the Solar Spectrum beyond the Red, obtained on a Collodion Plate. (Recd. Nov. 29, 1875. Read Jan. 20, 1876.)	'Proc. Roy. Soc.' xxiv 186–189.
Lecoq de Boisbaudran	Sur le spectre du gallium. (Read Jan. 10.)	'C. R.' lxxxii. 168; 'Phil. Mag.' [5] i. 176; 'J. Chem. Soc.' 1876, i. 882 (Abs.); 'Ber.' ix. 348 (Abs.); 'Am. J.' [3] xi. 320 (Abs.)
H. C. Sorby	On the Evolution of Hæmoglobin	'Quart. J. Mic. Sci.' xvi. 76–85.
A. Dupré	The Detection of the Colouring Matters of Logwood, Brazil-wood, and Cochineal in Wine. (Jan. 26.)	'Analyst,' i. 26; 'J. Chem. Soc.' 1877, i. 234 (Abs.)
W. de W. Abney	Preliminary Note on Photographing the Least Refracted Portion of the Solar Spectrum. (Read March 10.)	'Monthly Not. Astr. Soc.' xxxvi. 276–277; 'Phil. Mag.' [5] i. 414–415.
E. Vogel	The Relation between Spectral Lines and Atomic Weights. ('Scientific American.')	'Pharm. J. Trans.' [3] vi. 464–465.
M. Carey Lea	Notes on the Sensitiveness of Silver Bromide to the Green Rays as modified by the Presence of other Substances. (Mar. 13.)	'Am. J.' [3] xi. 459–464; 'J. Chem. Soc.' 1877, i. 266 (Abs.)
H. W. Vogel	Ueber die spectralanalytische Reaction auf Blut. (Mar. 1876. Read April 24.)	'Ber.' ix. 587–589.
H. Struve	Ueber das Vorkommen eines neuen, das Absorptionsspectrum des Blutes zeigenden Körpers im thierischen Organismus. (April 13. Recd. April 24.)	'Ber.' ix. 623–627.
W. de W. Abney	Photography of the Red and Ultra-Red end of the Spectrum.	'Nature,' xiii. 432.
J. Waterhouse	Photographic Action of Eosin. ('Photog. J.' xvi. 135–136.)	'J. Chem. Soc.' 1876, ii. 232 (Abs.)
H. W. Vogel	Neue Beobachtungen über die Lichtempfindlichkeit des Bromsilbers. (April 1876. Read May 8.)	'Ber.' ix. 667–670; 'J. Chem. Soc.' 1876, ii. 265 (Abs.)
H. C. Vogel and O. Lohse	Ueber die Photographie der weniger brechbaren Theile des Sonnenspectrums. (May 18.)	'Ann. Phys. u. Chem.' clix. 297–301.
C. Gänge	Zur Spectroskopie der Blutfarbstoffe. (May 1876. Recd. June 1.)	'Ber.' ix. 833–835; 'J. Chem. Soc.' 1876, ii. 646 (Abs.)

Chemical Relations, 1876, 1877.

J. L. W. Thudichum and C. T. Kingzett.	On Hemine, Hematine, and a Phosphorised Substance contained in Blood Corpuscles.	'J. Chem. Soc.' 1876, ii. 255–264.
M. Carey Lea . .	Dr. Vogel's Color Theory . .	'Am. J.' [3] xii. 48–50.
W. Gilmour .	The Spectroscope applied to the Detection of Adulteration, &c., of Fixed Oils.	'Pharm. J. Trans.' [3] vi. 981–982 ; vii. 22–23
H. W. Vogel . .	Zur Spectroscopie der Blutfarbstoffe. (Sept. 1876. Read Oct. 23.)	'Ber.' ix. 1472–1473.
" . .	Ueber eine empfindliche spectralanalytische Reaction auf Thonerde und Magnesia. (Oct. 1876. Read Nov. 13.)	'Ber.' ix. 1641–1646 ; 'J. Chem. Soc.' 1877, i. 742 (Abs.); 'Beiblätter,' i. 240–242 (Abs.)
J. Waterhouse. .	Ueber den Einfluss des Eosins auf die photographische Wirkung des Sonnenspectrums auf das Silberbromid und Silberbromojodid. ('Proc. Asiatic Soc. Bengal.')	'Ann. Phys. u. Chem.' clix. 616–622.
H. W. Vogel . .	Untersuchungen über Weinfälschungen. (Dec. 1876. Recd. Dec. 9.)	'Ber.' ix. 1906–1911.
F. von Lepel . .	Beitrag zur Kenntniss der spectralanalytischen Reaction auf Magnesiasalze. (Dec. 1876. Read Dec. 11.)	'Ber.' ix. 1845–1849; 'J. Chem. Soc.' 1877, i. 676 (Abs.); 'Beiblätter,' i. 240–242 (Abs.)

1877.

H. W. Vogel . .	Ueber die Purpurin-Thonerde-Magnesiareaction. (Jan. 1877. Read Jan. 15.)	'Ber.' x. 157–159 ; 'Beiblätter,' i. 240–242 (Abs.)
F. von Lepel . .	Ueber den Nachweis der Magnesia mit Hülfe des Spectroskopes. (Jan. 1877. Recd. Jan. 30.)	'Ber.' x. 159–165 ; 'Beiblätter,' i. 240–242 (Abs.)
H. Senier .	The Colouring Matter of the Petals of Rosa Gallica. (Read Feb. 7.)	'Pharm. J. Trans.' [3] vii. 650–652; 'J. Chem. Soc.' 1877, ii. 502 (Abs.)
Lecoq de Boisbaudran	Sur un nouveau métal, le gallium .	'Ann. Chim. et Phys.' [5] x. 100–141.
A. H. Church . .	Spectrum of Colein	'J. Chem. Soc.' 1877, i. 260.
P. Cazeneuve . .	Action de l'hydrosulphite de soude sur l'hématine du sang (hématine réduite.) (Read Feb. 16.)	'Bull. Soc. Chim.' [2] xxvii. 258–260 ; 'J. Chem. Soc.' 1877, ii. 346 (Abs.)
G. Chancel . .	Recherche et détermination des principales matières colorantes employées pour falsifier les vins. (Read Feb. 19.)	'C. R.' lxxxiv. 348–351 ; 'J. Chem. Soc.' 1877, ii. 371–372 (Abs.)
H. W. Vogel . .	Spectralanalytische Notizen. Absorptionsspectrum des Granats und des Rubins. Zur Purpurinmagnesiareaction. Erkennung von Thonerde neben Eisensalzen. (Feb. 1877. Read Feb. 26.)	'Ber.' x. 373–375 ; 'J. Chem. Soc.' 1877, ii. 269 (Abs.); 'Beiblätter,' i. 242 (Abs.)

CHEMICAL RELATIONS, 1877.

M. Carey Lea . .	On the Sensitiveness to Light of various Salts of Silver. (Mar. 22.)	'Am. J.' [3] xiii. 369–371; 'J. Chem. Soc.' 1877, ii. 690 (Abs.); 'Beiblätter,' i. 405 (Abs.)
H. W. Vogel . .	Ueber die Lichtempfindlichkeit des Purpurins. (April 9. Read April 9.)	'Ber.' x. 692; 'Beiblätter,' i. 288–289 (Abs.)
„ . .	Ueber die Nachweisung von Kohlenoxydgas. (April 1877. Read April 23.)	'Ber.' x. 792–795.
L. Liebermann .	Nachweis von Fuchsin im Weine. (Recd. April 28.)	'Ber.' x. 866; 'J. Chem. Soc.' 1877, ii. 939 (Abs.)
A. Jäderholm . .	Untersuchungen über den Blutfarbstoff und seine Derivate.	'Zeitschr. f. Biol.' xiii. 193–255; 'J. Chem. Soc.' xxxiv. 236–237 (Abs.)
C. Timiriazeff . .	Sur la décomposition de l'acide carbonique dans le spectre solaire par les parties vertes des végétaux. (Read May 28.)	'C. R.' lxxxiv. 1236–1239; 'J. Chem. Soc.' 1877, ii. 635–636 (Abs.)
M. Wiskemann .	Spectralanalytische Bestimmung des Hämoglobingehaltes des menschlichen Blutes.	'Zeitschr. f. Biol.' xii. 434–447; 'J. Chem. Soc.' 1877, ii. 808–809.
M. C. Lea . .	On the Theory of the Action of certain Organic Substances in increasing the Sensitiveness of Silver Haloids. (June 26.)	'Am. J.' [3] xiv. 96–99; 'Beiblätter,' i. 563 (Abs.)
P. Chastaing . .	Étude sur la part de la lumière dans les actions chimiques et en particulier dans les oxydations.	'Ann. Chim. et Phys.' [5] xi. 145–223; 'J. Chem. Soc.' 1877, ii. 818 (Abs.) 'Beiblätter,' i. 517–520 (Abs.)
S. Kern . . .	On some New Researches on the Metal Davyum.	'Chem. News,' xxxvi. 114.
„ . . .	On the Spectrum of the Metal Davyum.	„ xxxvi. 155.
„ . . .	Davyum	„ xxxvi. 164; 'Beiblätter,' i. 619.
G. Lemoine . .	Action de la lumière sur l'acide iodhydrique. (Read July 16.)	'C. R.' lxxxv. 144–147; 'Beiblätter,' i. 510 (Abs.)
J. H. Gladstone .	On some Points connected with the Chemical Constituents of the Solar System.	'Phil. Mag.' [5] iv. 379–385; 'J. Chem. Soc.' xxxiv. 189 (Abs.)
H. W. Vogel . .	Chastaing's neue Theorie der chemischen Wirkung des Lichts. (Oct. 1877. Read Oct. 15.)	'Ber.' x. 1638–1644; 'Beiblätter,' i. 681–682 (Abs.)
L. Dieulafait . .	L'acide borique	'Ann. Chim. et Phys.' [5] xii. 318–354; 'J. Chem. Soc.' xxxiv. 11–12 (Abs.)
C. Timiriazeff . .	Recherches sur la décomposition de l'acide carbonique dans le spectre solaire par les parties vertes des végétaux (extrait d'un ouvrage 'Sur l'assimilation de la lumière par les végétaux.' S. Pétersbourg, 1875.)	'Ann. Chim. et Phys.' [5] xii. 355–396.

CHEMICAL RELATIONS, 1877, 1878.

F. von Lepel	Spectralanalytische Notiz. (Oct. 1877. Recd. Oct. 29.)	'Ber.' x. 1875 1877; 'J. Chem. Soc.' xxxiv. 168 (Abs.)
G. Govi	De la loi d'absorption des radiations à travers les corps, et de son emploi dans l'analyse spectrale quantitative. (Read Dec. 3 and Dec. 10.)	'C. R.' lxxxv. 1046–1049, 1100–1103; 'Phil. Mag.' [5] v. 78–80; 'J. Chem. Soc.' xxxiv. 190–191 (Abs.); 'Beiblätter,' ii. 342–343 (Abs.)
A. Rosenstiehl	L'alizarine nitrée	'Ann. Chim. et Phys.' [5] xii. 519–529; 'J. Chem. Soc.' xxxiv. 231–232 (Abs.)

1878.

G. Hüfner	Ueber quantitative Spectralanalyse und ein neues Spectrophotometer.	'J. pr. Chem.' [2] xvi. 290–313; 'Zeitschr. Anal. Chem.' xviii. 451–457 (Abs.); 'Beiblätter,' ii. 151–152 (Abs.)
Sergius Kern	Davyum. ('La Nature')	'Nature,' xvii. 245–246.
Mascart	Sur la réfraction des gaz et des vapeurs. (Read Feb. 4.)	'C. R.' lxxxvi. 321–323.
,,	Sur la réfraction des gaz	'Ann. de l'école norm.' [2] vi. 9–78; 'Beiblätter,' i. 257–270.
E. Brücke	Ueber das Absorptionsspektrum des übermangansauren Kalis und seine Benutzung bei chemisch-analytischen Arbeiten.	'Chem. Centr.' [3] viii. 139–143; 'J. Chem. Soc.' xxxiv. 242–243 (Abs.)
K. Vierordt	Zur quantitativen Spectralanalyse. (Feb. 18.)	'Ann. Phys. u. Chem.' N.F. iii. 357–376.
R. Sachsse	Ueber eine neue Reaction des Chlorophylls.	'Chem. Centr.' [3] ix. 121–125; 'J. Chem. Soc.' xxxiv. 516 (Abs.)
C. Bardy	Das Chrysoidin, eine antiphotogenische Farbe.	'Chem. Centr.' [3] ix. 109; 'J. Chem. Soc.' xxxiv. 613 (Abs.)
T. Bayley	On the Colour Relations of Copper and its Salts.	'Phil. Mag.' [5] v. 222–224.
Dufet	Sur la variation des indices de réfraction dans les mélanges de sels isomorphes. (Read April 8.)	'C. R.' lxxxvi. 881–884; 'J. Chem. Soc.' xxxiv. 631–632.
W. de W. Abney	The Acceleration of Oxidation caused by the Least Refrangible End of the Spectrum (Preliminary Note). (Recd. March 16. Read April 11.)	'Proc. Roy. Soc.' xxvii. 291–292; 'J. Chem. Soc.' xxxviii. 429–430 (Abs.)
,,	Photography at the Least Refrangible End of the Solar Spectrum. (Read April 12.)	'Monthly Not. Astr. Soc.' xxxviii. 348–351; 'Phil. Mag.' [5] vi. 154–157.
J. L. Soret	Sur les spectres ultra-violets des terres de la gadolinite. (Read April 29.)	'C. R.' lxxxvi. 1062–1064; 'J. Chem. Soc.' xxxiv. 629 (Abs.); 'Beiblätter,' ii. 410–411 (Abs.)

CHEMICAL RELATIONS, 1878.

Mascart	Sur la réfraction des corps organiques considérés à l'état gazeux. (Read May 13.)	'C. R.' lxxxvi. 1182–1185; 'J. Chem. Soc.' xxxiv. 693 (Abs.)
W. de W. Abney	On the Acceleration of Oxidation by the Least Refrangible End of the Spectrum. Note II. (Recd. June 8. Read June 20.)	'Proc. Roy. Soc.' xxvii. 451–452; 'J. Chem. Soc.' xxxviii. 429–430 (Abs.)
T. Bayley	On the Analysis of Alloys containing Copper, Zinc, and Nickel.	'Phil. Mag.' [5] vi. 14–19.
J. Lawr. Smith	Le Mosandrum; un nouvel élément. (Read July 22.)	'C. R.' lxxxvii. 148–151.
F. v. Lepel	Zur Weinverfälschung. (July 21).	'Ber.' xi. 1552–1556.
G. Francis	A Poisonous Australian Lake. (Feb. 11.)	'Nature,' xviii. 11–12; 'Pharm. J. Trans.' [3] viii. 1047–1048; 'J. Chem. Soc.' xxxiv. 907 (Abs.)
W. de W. Abney	Physics in Photography	'Nature,' xviii. 489–491, 528–531, 543–546.
D. Tommasi	Azione dei raggi solari sui composti aloidi d'argento. (Read July 25.)	'Rend. del R. Ist. Lomb.' xi. 652–658; 'Beiblätter,' iii. 621–622 (Abs.)
C. Liebermann and K. Boeck.	Ueber Anthracendisulfosäure und deren Umwandlung in Anthrarufin. (Recd. Aug. 17.)	'Ber.' xi. 1613–1618; 'J. Chem. Soc.' xxxvi. 257–259 (Abs.)
M. Delafontaine	Sur un nouveau métal, le philippium. (Read Oct. 14.)	'C. R.' lxxxvii. 559–561; 'Am. J.' [3] xvii. 61 (Abs.); 'J. Chem. Soc.' xxxvi. 116–117 (Abs.); 'Beiblätter,' iii. 197–198 (Abs.)
C. Marignac	Sur l'ytterbine, nouvelle terre contenue dans la gadolinite. (Read Oct. 22.)	'C. R.' lxxxvii. 578–581; 'Am. J.' [3] xvii. 62–63 (Abs.); 'J. Chem. Soc.' xxxvi. 118–119 (Abs.)
M. Delafontaine	Sur le Mosandrum de M. Lawrence Smith. (Read Oct. 22.)	'C. R.' lxxxvii. 600–602; 'J. Chem. Soc.' xxxvi. 117 (Abs.)
H. Burger	Spectroskopische Untersuchungen über die Constitution von Lösungen. (Oct. 21. Read Oct. 28.)	'Ber.' xi. 1876–1878; 'J. Chem. Soc.' xxxvi. 101 (Abs.)
C. Marignac	Sur les terres de la gadolinite	'Ann. Chim. et Phys.' [5] xiv. 247–258; 'J. Chem. Soc.' xxxvi. 113–114 (Abs.)
M. Delafontaine	Sur le décipium, métal nouveau de la samarskite. (Read Oct. 28.)	'C. R.' lxxxvii. 632–634; 'J. Chem. Soc.' xxxvi. 117–118 (Abs.); 'Am. J.' [3] xvii. 61–62 (Abs.); 'Beiblätter,' iii. 197–198 (Abs.)

CHEMICAL RELATIONS, 1878, 1879.

M. Delafontaine .	Le didyme de la cérite est probablement un mélange de plusieurs corps. (Read Oct. 28.)	'C. R.' lxxxvii. 634–635; 'J. Chem. Soc.' xxxvi. 119 (Abs.); 'Beiblätter,' iii. 197–198 (Abs.)
J. N. Lockyer . .	Note préliminaire sur la nature composée des éléments chimiques. (Read Nov. 4.)	'C. R.' lxxxvii. 673.
P. Bert . . .	Sur la région du spectre solaire indispensable à la vie végétale. (Read Nov. 4.)	'C. R.' lxxxvii. 695–697; 'J. Chem. Soc.' xxxvi. 336 (Abs.)
W. G. Brown . .	Philippium. (Nov. 14) . . .	'Chem. News,' xxxviii. 267–268; 'J. Chem. Soc.' xxxvi. 204 (Abs.)
E. Yung . . .	De l'influence de différentes couleurs du spectre sur le développement des animaux. (Read Dec. 16.)	'C. R.' lxxxvii. 998–1000.
A. Cossa . . .	Sulla diffusione del Cerio, del Lantano e del Didimio.	'R. Acc. d. Lincei' [3] iii. 17–34; 'Beiblätter,' iv. 43–44 (Abs.)

1879.

F. Hoppe-Seyler .	Einfacher Versuch zur Demonstration der Sauerstoffausscheidung durch Pflanzen im Sonnenlichte.	'Zeitschr. f. Physiol. Chem.' ii. 425–426; 'Ber.' xii. 701–702 (Abs.); 'J. Chem. Soc.' xxxvi. 819 (Abs.)
Lecoq de Boisbaudran.	Le didyme de la samarskite diffère-t-il de celui de la cérite? (Read Feb. 17.)	'C. R.' lxxxviii. 322; 'Beiblätter,' iii. 358 (Abs.)
C. H. Wolff . .	Quantitative Spectralanalyse . .	'Zeitschr. Anal. Chem.' xviii. 38–49.
J. Petri . . .	Ueber den Nachweis von Mutterkorn im Mehle auf spectroskopischem Wege. (Jan. 1879.)	'Zeitschr. f. Ann. Chem.' xviii. 211–220; 'J. Chem. Soc.' xxxvi. 977–979 (Abs.)
G. Hüfner . .	Ueber die Bestimmung des Hämoglobin- und Sauerstoffgehaltes im Blute. (Dec. 5, 1878.)	'Zeitschr. f. Physiol. Chem.' iii. 1–18; 'Ber.' xii. 702 (Abs.); 'J. Chem. Soc.' xxxvi. 835 (Abs.)
	The Dissociation of the Elements.	'Chem. News,' xxxix. 65–66.
C. Cros . . .	De l'action des différentes lumières colorées sur une couche de bromure d'argent imprégnée de diverses matières colorantes organiques. (Read Feb. 24.)	'C. R.' lxxxviii. 379–381; 'J. Chem. Soc.' xxxvi. 504–505 (Abs.)
E. Becquerel . .	Remarques. (Read Feb. 24) . .	'C. R.' lxxxviii. 381–382.
J. L. Soret . .	Sur les spectres d'absorption du didyme et de quelques autres substances extraites de la samarskite. (Read March 3.)	,, lxxxviii. 422–424.
A. P. Smith . .	Blue Flame from Common Salt. (March 15.)	'Nature,' xix. 483; 'Chem. News,' xxxix. 141; 'J. Chem. Soc.' xxxvi. 497–498 (Abs.)

CHEMICAL RELATIONS, 1879.

L. F. Nilson . .	Ueber die Ytterbinerde. (March 12. Read March 24.)	'Ber.' xii. 550–553; 'J Chem. Soc.' xxxvi. 601 (Abs.)
,, . .	Om Scandium, en ny jordmetall. (Ueber Scandium, ein neues Erdmetall). (March 12. Read March 24.)	'Oefversigt af k. Vetenskaps Acad. Förhandlingar.' xxxvi. III. 45–51; 'Ber.' xii. 554–557; 'J. Chem. Soc.' xxxvi. 601 (Abs.); 'Beiblätter,' iv. 42 (Abs.)
,, . .	Sur l'ytterbine, terre nouvelle de M. Marignac. (March 12. Read March 24.)	'C. R.' lxxxviii. 642–645; 'Am. J.' [3] xvii. 478–479 (Abs.)
,, . .	Sur le scandium, élément nouveau. (Read March 24.)	'C. R.' lxxxviii. 645–648; 'Beiblätter,' iii. 359 (Abs.); 'Am. J.' [3] xvii. 478–479 (Abs.)
J. H. Gladstone .	Blue Flame from Common Salt. (April 10.)	'Nature,' xix. 582.
A. P. Smith . .	Blue Flame from Common Salt. (April 26.)	,, xx. 5.
A. Rosenstiehl .	Sur les spectres de l'alizarine et de quelques matières colorantes qui en dérivent. (Read June 9.)	'C. R.' lxxxviii. 1194–1196; 'J. Chem. Soc.' xxxvi. 807 (Abs.); 'Beiblätter,' iii. 792–793 (Abs.); 'Ber.' xii. 2080–2081 (Abs.)
Lecoq de Boisbaudran.	Examen spectral de l'erbine. (Read June 30.)	'C. R.' lxxxviii. 1342–1344; 'J. Chem. Soc.' xxxvi. 861 (Abs.); 'Am. J.' [3] xviii. 216–217; 'Beiblätter,' iii. 871 (Abs.)
H. Settegast . .	Beiträge zur quantitativen Spectralanalyse.	'Ann. Phys. u. Chem.' N.F. vii. 242–271; 'J. Chem. Soc.' xxxvi. 828–829 (Abs.)
G. Fraude . .	Ueberchlorsäure, ein neues Reagens auf Alkaloide. (Recd. July 23. Read July 28.)	'Ber.' xii. 1558–1560.
Lecoq de Boisbaudran.	Recherches sur le samarium, radical d'une terre nouvelle extraite de la samarskite. (Read July 28.)	'C. R.' lxxxix. 212–214; 'Ber.' xii. 2160 (Abs.); 'Beiblätter,' iii. 872 (Abs.)
P. T. Clève . .	Sur deux nouveaux éléments dans l'erbine. (Read Sept. 1.)	'C. R.' lxxxix. 478–480; 'Am. J.' [3] xviii. 400–401; 'Beiblätter,' iv. 43 (Abs.)
L. Smith . .	Remarques	'C. R.' lxxxix. 480–481; 'Beiblätter,' iv. 43 (Abs.)
W. Thörner . .	Ueber den im Ag. atrotomentosus vorkommenden chinonartigen Körper. (Recd. Aug. 11.)	'Ber.' xii. 1630–1635.
J. N. Lockyer . .	Expériences tendant à démontrer la nature composée du phosphore. (Read Sept. 15.)	'C. R.' lxxxix. 514–515; 'Beiblätter,' iv. 132 (Abs.)

CHEMICAL RELATIONS, 1879, 1880.

Lecoq de Boisbaudran.	Recherches sur l'erbine. (Read Sept. 15.)	'C. R.' lxxxix. 516–517; 'Beiblätter,' iv. 43 (Abs.)
J. L. Soret . .	Sur le spectre des terres faisant partie du groupe de l'yttria. (Read Sept. 15.)	'C. R.' lxxxix. 521–523; 'Ber.' xii. 2267–2268; 'J. Chem. Soc.' xxxviii. 7 (Abs.); 'Beiblätter,' iv. 43 (Abs.)
P. T. Clève . .	Sur l'erbine. (Read Oct. 27) . .	'C. R.' lxxxix. 708–709.
J. W. Brühl . .	Die chemische Constitution organischer Körper in Beziehung zu deren Dichte und ihrem Vermögen das Licht fortzupflanzen. Part I. (Oct. 1879.)	'Ann. Chem. u. Pharm.' cc. 139–231; 'J. Chem. Soc.' xxxviii. 295–297 (Abs.); 'Beiblätter,' iv. 776–786 (Abs.)
,, . .	Die Beziehungen zwischen den physikalischen Eigenschaften organischer Körper und ihrer chemischen Constitution. (Nov. 1879.)	'Ber.' xii. 2135–2148, xiii. 1119–1130, 1520–1535; 'J. Chem Soc.' xxxviii. 293–295 (Abs.); 'Beiblätter,' iv. 776–786 (Abs.)
C. von Noorden .	Beiträge zur quantitativen Spectralanalyse, insbesondere zu derjenigen des Blutes. (Nov. 1879.)	'Zeitschr. f. Physiol. Chem.' iv. 9–35; 'Ber.' xiii. 439 (Abs.)
G. D. Liveing and J. Dewar.	Quantitative Spectroscopic Experiments. (Recd. Nov. 27. Read Dec. 11.)	'Proc. Roy. Soc.' xxix. 482–489; 'Beiblätter,' iv. 367 (Abs.)
H. W. Vogel . .	Spectroskopische Notizen. Die Wasserstoffflamme in der Spectralanalyse. Ueber die Erkennung des Kobalts neben Eisen und Nickel. (Dec. 15.)	'Ber.' xii. 2313–2316; 'Beiblätter,' iv. 278 (Abs.), v. 118 (Abs.)

1880.

B. Nickels . .	On the Use of the Spectroscope in discriminating Anthracens.	'Chem. News,' xli. 52, 95–97; 'Ber.' xiii. 829 (Abs.); 'J. Chem. Soc.' xxxviii. 757 (Abs.)
M. Delafontaine .	Remarques sur les métaux nouveaux de la gadolinite et de la samarskite. (Read Feb. 2.)	'C. R.' xc. 221–223.
,, .	Sur le décipium et ses principaux composés. (Feb. 14.)	'Arch. de Genève' [3] iii. 250–260; 'Beiblätter,' iv. 549 (Abs.)
C. A. MacMunn .	Researches into the Colouring Matters of Human Urine, with an Account of the Separation of Urobilin. (Recd. Mar. 6. Read Mar. 18.)	'Proc. Roy. Soc.' xxxi. 26–36, xxx. 250–252 (Abs.); 'Beiblätter,' v. 47 (Abs.); 'Ber.' xiv. 1212–1214 (Abs.)
J. L. W. Thudichum	On the Modifications of the Spectrum of Potassium which are Effected by the Presence of Phosphoric Acid, and on the Inorganic Bases and Salts which are found in Combination with Educts of the Brain. (Recd. Mar. 10. Read Mar. 18.)	'Proc. Roy. Soc.' xxx. 278–286.

CHEMICAL RELATIONS, 1880.

J. W. Brühl . .	Die chemische Constitution organischer Körper in Beziehung zu deren Dichte und ihrem Vermögen das Licht fortzupflanzen. Part II. (Mar. 1880.)	'Ann. Chem. u. Pharm.' cciii. 1–63; 'J. Chem. Soc.' xxxviii.; 781–783 (Abs.); 'Beiblätter,' iv. 776–786 (Abs.)
F. v. Lepel . .	Der Alkannafarbstoff, ein neues Reagens auf Magnesiumsalze. (Mar. 1880.)	'Ber.' xiii. 763–766.
" . .	Pflanzenfarbstoffe als Reagentien auf Magnesiumsalze. (Mar. 1880.)	'Ber.' xiii. 766–768; 'J. Chem. Soc.' xl. 63 (Abs.)
	Colouring Matter of Pentacrinus .	'Nature,' xxi. 593.
J. W. Brühl . .	Die chemische Constitution organischer Körper in Beziehung zu deren Dichte und ihrem Vermögen das Licht fortzupflanzen. Part III. (April 1880.)	'Ann. Chem. u. Pharm.' cciii. 255–285; 'Beiblätter,' iv. 776–786 (Abs.)
C. Marignac . .	Sur les terres de la samarskite. (Read April 19.)	'C. R.' xc. 899–903.
B. Radziszewski .	Ueber die Phosphorescenz der organischen und organisirten Körper. (April 1880.)	'Ann. Chem. u. Pharm.' cciii. 305–336; 'Beiblätter,' iv. 620 (Abs.)
L. Calderon . .	Ueber die optischen Eigenschaften der Zinkblende von Santander.	'Zeitschr. f. Kryst. u. Mineral.' iv. 504–517; 'Beiblätter,' v. 361–362 (Abs.)
J. W. Brühl . .	Die chemische Constitution organischer Körper in Beziehung zu deren Dichte und ihrem Vermögen das Licht fortzupflanzen. Nachtrag. (June 1880.)	'Ann. Chem. u. Pharm.' cciii. 363–368; 'Beiblätter,' iv. 776–786 (Abs.)
R. Thalén . .	Sur les raies brillantes spectrales du métal scandium. (Read July 5.)	'C. R.' xci. 45–48; 'J. Chem. Soc.' xxxviii. 685 (Abs.); 'Beiblätter,' iv. 787–789 (Abs.)
W. R. Dunstan .	The Relation between the Chemical Constitution of certain Organic Compounds and their Action upon the Ultra-violet Rays. (July 8.)	'Pharm. J. Trans.' [3] xi. 54–56.
A. Fock . . .	Ueber die Aenderung der Brechungsexponenten isomorpher Mischungen, mit deren chemischer Zusammensetzung.	'Zeitschr. f. Kryst. u. Mineral.' iv. 583–608; 'Beiblätter,' iv. 662–664 (Abs.)
G. Hüfner . .	Untersuchungen zur physikalischen Chemie des Blutes. (July 1880.)	'J. pr. Chem.' [2] xxii. 362–388; 'J. Chem. Soc.' xl. 111–113 (Abs.)
W. Voigt . .	Ueber den Einfluss einer Krümmung der Prismenflächen auf die Messungen von Brechungsindices und über die Beobachtungen des Herrn Calderon an der Zinkblende. (July 1880.)	'Zeitschr. f. Kryst. u. Mineral.' v. 113–130; 'Beiblätter,' v. 361–362 (Abs.)
R. Thalén . .	Sur les spectres de l'ytterbium et de l'erbium. (Read Aug. 9.)	'C. R.' xci. 326–328; 'Beiblätter,' v. 122 (Abs.)

CHEMICAL RELATIONS, 1880, 1881.

R. Thalén	Examen spectrale du thulium. (Read Aug. 16.)	'C. R.' xci. 376–378; 'J. Chem. Soc.' xl. 349–350 (Abs.); 'Beiblätter,' iv. 789 (Abs.)
A. Dupré	The Detection of Foreign Colouring Matters in Wine.	'J. Chem. Soc.' xxxvii. 572–575; 'Ber.' xiii. 2004–2005 (Abs.)
E. Schunk	Note on the Purple of the Ancients	'J. Chem. Soc.' xxxvii. 613–617.
C. Wesendonck	Ueber Spectra der Kohlenstoffverbindungen. (Recd. Aug. 20. Read Oct. 18.)	'Monatsb. Berl. Akad.' 1880, 791–794.
H. Morton	Displacement of the Absorption Bands of Purpurin in Solutions of Alum.	'Chem. News,' xlii. 207 (Abs.); 'J. Chem. Soc.' xl. 488 (Abs.)
W. de W. Abney	On the Reversal of the Developed Photographic Image.	'Phil. Mag.' [5] x. 200–208.
W. N. Hartley	An Examination of Terpenes for Cymene by means of the Ultra-violet Spectrum.	'J. Chem. Soc.' xxxvii. 676–678.
J. H. Gladstone	Specific Refraction and Dispersion of Isomeric Bodies. (Read Nov. 27.)	'Proc. Phys. Soc.' iv. 94–100; 'Phil. Mag.' [5] xi. 54–60; 'Ber.' xiv. 835 (Abs.); 'J. Chem. Soc.' xl. 213–214 (Abs.); 'Beiblätter,' v. 276–278 (Abs.)
Lecoq de Boisbaudran	Réaction spectrale du chlore et du brome. (Read Dec. 6.)	'C. R.' xci. 902–903; 'Beiblätter,' v. 118 (Abs.); 'Phil. Mag.' [5] xi. 77–78.
C. A. MacMunn	Further Researches into the Colouring matters of Human Urine, with an Account of their Artificial Production from Bilirubin and from Hæmatin. (Recd. Nov. 10. Read Dec. 16.)	'Proc. Roy. Soc.' xxxi. 206–237; 'J. Chem. Soc.' xl. 1056–1058 (Abs.); 'Beiblätter,' v. 281 (Abs.); 'Ber.' xiv. 1212–1214 (Abs.)
T. Bayley	On the Colour Properties and Relations of the Metals Copper, Nickel, Cobalt, Iron, Manganese, and Chromium.	'J. Chem. Soc.' xxxvii. 828–836.

1881.

R. Meldola	On a New Class of Colouring Matters from the Phenols.	'J. Chem. Soc.' xxxix. 37–40.
P. Hautefeuille and J. Chappuis.	De la recherche des composés gazeux et de l'étude de quelques-unes de leurs propriétés à l'aide du spectroscope. (Read Jan. 10.)	'C. R.' xcii. 80–82; 'J. Chem. Soc.' xl. 221–222 (Abs.); 'Beiblätter,' v. 317 (Abs.)
S. Wleügel	Zur spectralanalytischen Ermittelung des Indiums. ('Corr.-Bl. d. Ver. analyt. Chemiker,' iii. 39.)	'Zeitsch. f. Anal. Chem.' xx. 115 (Abs.); 'Beiblätter,' v. 281 (Abs.)
J. H. Gladstone	The Refraction Equivalents of Carbon, Hydrogen, Oxygen, and Nitrogen in Organic Compounds. (Recd. Jan. 4. Read Jan. 27.)	'Proc. Roy. Soc.' xxxi. 327–330; 'Ber.' xiv. 1553–1554 (Abs.)

CHEMICAL RELATIONS, 1881—THEORETICAL PAPERS, 1871.

J. Macagno . .	Lo Spettroscopio applicato alla ricerca dei colori di anilina introdotti nei vini rossi per sofisticazione. (Feb. 15.)	'Mem. Spettr. ital.' 1881, 35–40; 'Ber.' xiv. 1584 (Abs.)
W. de W. Abney and R. Festing.	On the Influence of the Molecular Grouping in Organic Bodies on their Absorption in the Infra-Red Region of the Spectrum. (Recd. Feb. 5. Read Feb. 10.)	'Proc. Roy. Soc.' xxxi. 416–417 (Abs.); 'Chem. News,' xliii. 75 (Abs.); 'J. Chem. Soc.' xl. 487–488 (Abs.); 'Beiblätter,' v. 506 (Abs.)
W. N. Hartley . .	On the Absorption of Solar Rays by Atmospheric Ozone. Part I.	'J. Chem. Soc.' xxxix. 111–128; 'Ber.' xiv. 1390 (Abs.)
,, . .	Researches on the Relation between the Molecular Structure of Carbon Compounds and their Absorption Spectra.	'J. Chem. Soc.' xxxix. 153–168.
W. J. Russell and W. Lapraik.	On Absorption-bands in the Visible Spectrum produced by certain Colourless Liquids.	'J. Chem. Soc.' xxxix. 168–173; 'Am. J.' [3] xxi. 500–501 (Abs.)
H. W. Vogel . .	Ueber die Empfindlichkeit trockner Bromsilberplatten gegen das Sonnenspecktrum. (Read April 25.)	'Ber.' xiv. 1024–1028; 'Beiblätter,' v. 521 (Abs.); 'J. Chem. Soc.' xl. 773 (Abs.)
T. Bayley . .	On the Colour Properties and Colour Relations of the Metals of the Iron-Copper Group.	'J. Chem. Soc.' xxxix. 362–370.
J. Kannonikow .	Zur Frage über den Einfluss der Struktur auf das Lichtbrechungsvermögen organischer Verbindungen. ('J. russ. physiol.-chem. Ges.' 1881, 268.)	'Ber.' xiv. 1697–1700 (Abs.)
C. Wesendonck .	Note on the Spectrum of Carbonic Acid. (Recd. May 16. Read June 16.)	'Proc. Roy. Soc.' xxxii. 380–382; 'Chem. News,' xliv. 42–43; 'J. Chem. Soc.' xl. 861–862 (Abs.)

THEORETICAL PAPERS.

1871.

G. J. Stoney . .	On the Cause of the Interrupted Spectra of Gases. (Read Jan. 9.)	'Proc. Roy. Irish Acad.' i. 107–112 (Abs.); 'Phil. Mag.' [4] xli. 291–296; 'Ann. Chim. et Phys.' [4] xxvi. 265–266 (Abs.)
G. J. Stoney and J. Emerson Reynolds.	An Inquiry into the Cause of the Interrupted Spectra of Gases. Part II. On the Absorption Spectrum of Chlorochromic Anhydride.	'Roy. Irish Acad.' June 12; 'Phil. Mag.' [4] xlii. 41–52; 'Ann. Chim. et Phys.' [4] xxvi. 266–268 (Abs.) 'Arch. de Genève,' xlii. 80–82 (Abs.)
J. L. Soret . .	Observation sur la note précédente.	'Arch. de Genève,' xlii. 82–84; 'Phil. Mag.' xlii. 464–465; 'Ann. Chim. et Phys.' [4] xxvi. 269.

THEORETICAL PAPERS, 1871–1873.

G. B. Airy . .	Corrections to the Computed Lengths of Waves of Light, published in the 'Philosophical Transactions' of the year 1868. (Recd. Oct. 2. Read Nov. 16.)	'Phil. Trans.' 1872, cxlii. 89–109; 'Proc. Roy. Soc.' xx. 21–22 (Abs.)
W. Sellmeier . .	Ueber die durch die Aetherschwingungen erregten Mitschwingungen der Körpertheilchen und deren Rückwirkung auf die erstern, besonders zur Erklärung der Dispersion und ihrer Anomalien.	'Ann. Phys. u. Chem.' cxlv. 399–421, 520–549; cxlvii. 386–403, 525–554.
	1872.	
J. Herschel . .	Spectroscopic Nomenclature. (Mar. 19.)	'Nature,' v. 499–500.
C. A. Young . .	Ditto. (May 16) . . .	„ vi. 101.
Ditscheiner . .	On the Wave-lengths of Fraunhofer's Lines.	'Am. J.' [3] iii. 297–299.
J. Silbermann . .	Mémoire sur des faits dont on peut déduire: 1° une théorie des aurores boréales et australes, fondée sur l'existence de marées atmosphériques; 2° l'indication, à l'aide des aurores, de l'existence d'essaims d'étoiles filantes à proximité du globe terrestre. (Read Feb. 19 and 26.)	'C. R.' lxxiv. 553–557, 638–642.
Faye . . .	Note sur l'association nouvellement fondée en Italie sous le titre de 'Società dei Spettroscopisti Italiani.' (Read April 1.)	'C. R.' lxxiv. 913–918.
O. E. Meyer . .	Versuch einer Erklärung der anomalen Farbenzerstreuung. (Christmas, 1871.)	'Ann. Phys. u. Chem.' cxlv. 80–86; 'Ann. Chim. et Phys.' [4] xxv. 423 (Abs.)
Hon. J. W. Strutt .	On the Reflection and Refraction of Light by intensely Opaque Matter. (April 5.)	'Phil. Mag.' [4] xliii. 321–338.
Tacchini . . .	Lettre à M. Faye à propos de sa Note présentée à l'Académie le 1er avril dernier, sur l'organisation de la Société des Spectroscopistes italiens. (Read May 6.)	'C. R.' lxxiv. 1237–1240.
Faye . . .	Réponse à la lettre précédente de M. Tacchini. (Read May 6.)	„ lxxiv. 1240–1243.
J. Herschel . .	Spectral Nomenclature. (July 29.)	'Nature,' vi. 433–434.
Faye . . .	Complément de la théorie physique du Soleil; explication des taches. (Read Dec. 16.)	'C. R.' lxxv. 1664–1672.
„ . . .	Explication des taches. (Suite.) (Read Dec. 30.)	„ lxxv. 1793–1796.
	1873.	
Faye . . .	Explication des taches solaires. Réponse à une critique des 'Memorie degli Spettroscopisti italiani.' (Read Feb. 10.)	'C. R.' lxxvi. 301–310.

THEORETICAL PAPERS, 1873.

Faye . . .	Explication des taches solaires. Fin de la réponse aux critiques de MM. Tacchini et Secchi. (Read Feb. 17.)	'C. R.' lxxvi. 389–397.
A. Secchi . .	Sur la nature et l'origine des taches solaires. (Feb. 21. Read Mar. 3.)	„ lxxvi. 519–527.
Faye . . .	Sur la nouvelle hypothèse du P. Secchi. (Read Mar. 10.)	„ lxxvi. 593–597.
„ . . .	Sur la circulation de l'hydrogène solaire, avec une réponse à un point de la note de M. Tacchini. (Read Mar. 10.)	„ lxxvi. 597–601.
Tacchini . . .	Sur la théorie des taches solaires. Réponse à deux notes précédentes de M. Faye. (Mar. 2. Read Mar. 10.)	„ lxxvi. 633–635.
E. Vicaire . .	Observations sur la théorie des cyclones solaires. (Read March 17.)	„ lxxvi. 703–706.
Faye . . .	Note sur quelques points de la théorie des cyclones solaires, en réponse à une critique de M. Vicaire. (Read Mar. 24.)	„ lxxvi. 733–741.
Tacchini . .	Sur quelques points de la théorie émise par M. Faye pour l'explication des taches solaires. (Mar. 22. Read Mar. 31.)	„ lxxvi. 826–830.
A. Secchi. . .	Sur la théorie des taches solaires. Réponse à M. Faye. (Read April 14.)	„ lxxvi. 911–919.
Faye . . .	Réponse au P. Secchi et à M. Vicaire. (Read April 14.)	„ lxxvi. 919–923.
E. Vicaire . .	Nouvelles observations sur la théorie des cyclones solaires. (Read April 14.)	„ lxxvi. 948–952.
Faye . . .	Réponse finale au P. Secchi. (Read April 21.)	„ lxxvi. 977–982.
„ . . .	Note sur les cyclones solaires, avec une réponse de M. Respighi à MM. Vicaire et Secchi. (Read May 19.)	„ lxxvi. 1229–1232.
E. Vicaire . .	Sur la théorie des taches et sur le noyau obscur du Soleil. (Read June 9.)	„ lxxvi. 1396–1399.
„ . .	Sur la constitution du Soleil et la théorie des taches. (Read June 23.)	„ lxxvi. 1540–1544.
„ . .	Sur la constitution du Soleil et la théorie des taches. (Read July 7.)	„ lxxvii. 40–44.
H. Tarry . . .	Les cyclones du Soleil comparés à ceux de notre atmosphère. (Read July 7.)	„ lxxvii. 44–48.
Tacchini . . .	Nouvelles observations spectrales, en désaccord avec quelques-unes des théories émises sur les taches solaires. (July 11. Read July 21.)	„ lxxvii. 195–198.

THEORETICAL PAPERS, 1873, 1874.

Faye . . .	Sur la théorie physique du Soleil proposée par M. Vicaire. (Read Aug. 4.)	'C. R.' lxxvii. 293–301.
,, . . .	Réponse à de nouvelles objections de M. Tacchini. (Read Aug. 11.)	,, lxxvii. 381–388.
,, . . .	Theorie des scories solaires, selon M. Zöllner. (Read Aug. 25.)	,, lxxvii. 501–509.
Tacchini . . .	Nouvelles observations relatives à la présence du magnésium sur le bord du Soleil, et réponse à quelques points de la théorie émise par M. Faye. (Aug. 27. Read Sept. 8.)	,, lxxvii. 606–609.
Faye .	Réponse à la dernière note de M. Tacchini. (Read Sept. 15.)	,, lxxvii. 621–627.
,, . . .	Sur l'explication des taches solaires proposée par M. le Dr. Reye. (Read Oct. 20.)	,, lxxvii. 855–861.
H. Tarry . .	Procédé pour déterminer la direction et la force du vent ; suppression des girouettes; application aux cyclones. (Read Nov. 10.)	,, lxxvii. 1117–1120.
Faye . . .	Réponse aux remarques de M. Tarry sur la théorie des taches solaires. (Read Nov. 17.)	,, lxxvii. 1122–1130.
T. Reye . . .	Réponse à M. Faye concernant les taches solaires. (Read Nov. 17.)	,, lxxvii. 1178–1181.
Marié-Davy . .	Observations, à propos d'une note récente de M. Reye, sur les analogies qui existent entre les taches solaires et les tourbillons de notre atmosphère. (Read Nov. 24.)	,, lxxvii. 1227–1229.
H. de Parville . .	Note sur les cyclones terrestres et les cyclones solaires. (Read Nov. 24.)	,, lxxvii. 1230–1233.
E. Vicaire . .	Sur la constitution physique du Soleil. Réponse aux critiques de M. Faye. (Read Dec. 22.)	,, lxxvii. 1491–1495.
	1874.	
Lord Rayleigh .	On the Manufacture and Theory of Diffraction Gratings.	'Phil. Mag.' [4] xlvii. 81–93, 193–205.
T. Reye . . .	Noch einmal meine Bedenken gegen die Zöllner'sche Erklärung der Sonnenflecke und Protuberanzen. (Feb. 18.)	'Ann. Phys. u. Chem.' cli. 166–173.
F. Zöllner . .	Ueber den Aggregatzustand der Sonnenflecke.	'Ann. Phys. u. Chem.' clii. 291–310.
C. Niven . .	On a Method of finding the Parallax of Double Stars, and on the Displacement of the Lines of the Spectrum of a Planet. (April 11. Read May 8.)	'Monthly Not. Astr. Soc.' xxxiv. 339–347.
Faye . . .	Théories solaires. Réponse à quelques critiques récentes. (Read June 15.)	'C. R.' lxxviii. 1663–1670.

THEORETICAL PAPERS, 1874–1876.

Tacchini . . .	Sur la formation des taches solaires. (Read July 6.)	'C. R.' lxxix. 39–41.
Faye . . .	Observations au sujet de la dernière note de M. Tacchini, et du récent mémoire de M. Langley. (Read July 13.)	„ lxxix. 74–82.
„ . .	Double série de dessins représentant les trombes terrestres et les taches solaires, exécutés par M. Faye. (Read Aug. 3.)	„ lxxix. 265–273.
„ . . .	À la Société des Spectroscopistes italiens. (Read Aug. 31.)	„ lxxix. 549–557.
H. Helmholtz . .	Zur Theorie der anomalen Dispersion. (Read Oct. 29.)	'Monatsb. Berl. Akad.' 1874, 667–680; 'Ann. Phys. u. Chem.' cliv. 582–596.
	1875.	
Faye . . .	Sur le dernier numéro des 'Memorie dei Spettroscopisti italiani.' (Read April 12.)	'C. R.' lxxx. 935–936.
E. Lommel . .	Elementare Behandlung einiger optischen Probleme.	'Ann. Phys. u. Chem.' clvi. 578–590.
E. von Benkovich .	Zur Theorie des Assimilationsprocesses in der Pflanzenwelt.	'Ann. Phys. u. Chem.' cliv. 468–473.
	1876.	
G. G. Stokes . .	On the Early History of Spectrum Analysis. (Letter to C. T. L. Whitmell.)	'Nature,' xiii 188–189.
A. M. Mayer . .	The History of Young's Discovery of his Theory of Colour. (Dec. 13, 1875.)	'Phil. Mag.' [5] i. 111–127.
Lecoq de Boisbaudran.	Théorie des spectres: observations sur la dernière communication de M. Lockyer. (Read May 29.)	'C. R.' lxxxii. 1264–1266; 'J. Chem. Soc.' 1876, ii. 470 (Abs.)
F. W. Berg . .	Ueber die kleinste Ablenkung im Prisma. (May 1876.)	'Ann. Phys. u. Chem.' clviii. 651–653.
E. Ketteler . .	Attempt at a Theory of the (Anomalous) Dispersion of Light in Singly and Doubly Refracting Media. ('Verhandl. d. Naturhist. Vereins d. Preuss. Rheinlande und Westphalens,' xxxiii.)	'Phil. Mag.' [5] ii. 332–345, 414–422, 508–522.
E. Lommel . .	Ueber die kleinste Ablenkung im Prisma.	'Ann. Phys. u. Chem.' clix. 329–330.
E. Ketteler . .	Zum Zusammenhang zwischen Absorption und Dispersion. (Sept. 1876.)	'Ann. Phys. u. Chem.' clx. 466–486.
Tacchini . . .	Sur les taches solaires. (Read May 14.)	'C. R.' lxxxiv. 1079–1081.
J. Janssen . .	Réponse à la note de M. Tacchini insérée au dernier 'Compte Rendu,' séance du 14 mai 1877. (Read May 28.)	„ lxxxiv. 1182–1183.

THEORETICAL PAPERS, 1876–1881.

E. Ketteler . .	Notiz, betreffend die Dispersionscurve der Mittel mit mehr als Einem Absorptionsstreifen. (March 1877.)	'Ann. Phys. u. Chem.' N.F. i. 340–351.

1878.

E. Lommel . .	Theorie der Absorption und Fluorescenz. (Oct. 1877.)	'Ann. Phys. u. Chem.' N.F. iii. 251–283.
,, . .	Theorie der normalen und anomalen Dispersion. (Dec. 1877.)	'Ann. Phys. u. Chem.' N.F. iii. 339–356.
H. Hartshorne .	Note on the Theoretical Explanation of Fraunhofer's Lines.	'J. Franklin Inst.' lxxv. 38–43; 'Les Mondes,' xlv. 517–522; 'Beiblätter,' ii. 561 (Abs.)
Favé . . .	Les vibrations de la matière et les ondes de l'éther dans les combinaisons photochimiques. (Read March 4.)	'C. R.' lxxxvi. 560–565.
Thollon . . .	Théorie du nouveau spectroscope à vision directe. (Read March 4.)	'C. R.' lxxxvi. 595–598; 'Beiblätter,' ii. 253–254 (Abs.)
E. Wiedemann .	Untersuchungen über die Natur der Spectra: 1, Theorie; 2, Spectra gemischter Gase. (Aug. 1878.)	'Ann. Phys. u. Chem.' N.F. v. 500–524; 'Phil. Mag.' [5] vii. 77–95; 'Am. J.' xvii. 250–251.
G. F. Becker . .	A Contribution to the History of Spectrum Analysis.	'Am. J.' [3] xvi. 392–393.

1879.

Mouton . . .	Sur les Lois de la Dispersion. (Read June 9.)	'C. R.' lxxxviii. 1189–1192; 'Beiblätter,' iii. 616–618 (Abs.)
E. Lommel . .	Ueber eine zweiconstantige Dispersionsformel.	'Ann. Phys. u. Chem.' N.F. viii. 628–634.
J. N. Lockyer . .	On the Necessity for a New Departure in Spectrum Analysis.	'Nature,' xxi. 5–8; 'Beiblätter,' iv. 363–364 (Abs.)
Lord Rayleigh .	Investigations in Optics, with Special Reference to the Spectroscope.	'Phil. Mag.' [5] viii. 261–274, 403–411, 477–486; ix. 40–55; 'Beiblätter,' iv. 360 (Abs.)

1880.

O. N. Rood . .	On Newton's use of the term Indigo with reference to a Color of the Spectrum.	'Am. J.' [3] xix. 135–137; 'Beiblätter,' iv. 460–461 (Abs.)
B. C. Brodie . .	Dissociation of the Metalloid Elements. (March 14.)	'Nature,' xxi. 491–492.
F. Lippich . .	Untersuchungen über die Spectra gasförmiger Körper. (Read May 13.)	'Sitzungsb. Wien. Akad.' lxxxii. II. 15–33.

1881.

E. Lommel . .	Ueber das Dispersionsgesetz. (April 1881.)	'Ann. Phys. u. Chem. N.F. xiii. 353–360.

In the foregoing list there are doubtless many inaccuracies and omissions. Although some trouble has been taken to render the list correct as far as it goes, yet it is certainly incomplete. It is requested that anyone detecting errors will communicate with some member of the Committee, forwarding the proper correction. The reliance that can be placed on the list will best be indicated by a description of the method employed in compiling it.

The following periodicals were looked through: 'Philosophical Transactions,' 'Proceedings of the Royal Society,' 'Philosophical Magazine,' 'Journal of the Chemical Society,' 'Monthly Notices of the Royal Astronomical Society,' 'Nature,' 'Comptes Rendus de l'Académie des Sciences,' 'Annales de Chimie et de Physique,' 'Berichte der Deutschen Chemischen Gesellschaft,' 'Annalen der Physik und Chemie,' 'Beiblätter zu den Annalen der Physik und Chemie,' 'American Journal of Science and Arts.' In many of these periodicals, abstracts from others, and also references, were found; the originals of these were then sought and the titles entered in the list. Almost all the references in the third column have been thus verified; those in the second column (immediately following the titles) have not been verified, but are entered as found in the abstracts.

Interim Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements, the Committee consisting of Professor G. CAREY FOSTER, Mr. C. HOCKIN, Professor Sir WILLIAM THOMSON, Professor AYRTON, Mr. J. PERRY, Professor W. G. ADAMS, Lord RAYLEIGH, Professor F. JENKIN, Dr. O. J. LODGE, Dr. JOHN HOPKINSON, Dr. MUIRHEAD, Mr. W. H. PREECE, *and* Mr. HERBERT TAYLOR.

[PLATE VI.]

IT appeared to the Committee that in order to perform the task entrusted to them, they had two principal questions to consider: First, to select or prepare a well-defined standard of accurately known absolute value for each kind of magnitude; and, secondly, to take measures for making certified copies of each of the adopted standards accessible to the public.

The standard magnitudes which the Committee have had under consideration as yet are—

1. The Standard of Resistance.
2. The Standard of Capacity.
3. The Standard of Electromotive Force.

As to the first of these, the standard of *Resistance*, the Committee were of opinion that, in view of the discrepant results obtained by experimenters who have re-examined the absolute resistance of the B. A. unit, it might be well to reconsider the question whether the 'ohm' should be defined by reference to a particular coil of wire preserved as a concrete standard, or whether the term 'ohm' should be understood to mean a resistance of 10^9 C. G. S. units. They were also of opinion that it was desirable to continue the experimental investigation of the absolute resistance of the existing standards.

The repetition of the determination with the original apparatus, by Lord Rayleigh and Professor Schuster in the Cavendish Laboratory, has gone far to supply this requirement. Experiments by another method have also been carried on by Professor G. C. Foster in the Physical Laboratory of University College, London. Some account of these experiments is given in Appendix I. to this report, but the results hitherto obtained can only be regarded as preliminary. With regard to the issue of authorised copies of the ohm for general use, the Committee did not see their way to making arrangements for actual construction of standard coils. They were of opinion that it would be best to limit their action to drawing up a detailed specification for the construction of standard resistance coils, and to arranging for the systematic testing of coils which are certified to them as being made in accordance with this specification, issuing certificates showing their actual resistance. Such a system would be analogous to the system adopted by the Kew Committee for the testing of meteorological instruments at the Kew Observatory. It has not yet been settled by whom this duty should be undertaken.

An important point of detail connected with the practical construction and use of standard coils has been investigated by Mr. Herbert Taylor. The material adopted by the former Committee for the wire of the standards issued by them, was an alloy of platinum and silver, containing one part platinum to two of silver; and the same material is very often used for the coils in the 'resistance-boxes' issued by instrument-makers. One special reason for the selection of this alloy for the purpose named is its small temperature-rate of variation of resistance,—0·031% per degree, according to the late Dr. Matthiessen. Mr. Taylor has now found that the rate of variation of resistance of wire made of this alloy depends upon the diameter of the wire, the percentage amount for one degree varying from 0·0299 for a wire nearly 7 millim. in diameter to 0·0231 for a wire of diameter 0·168 millim. A detailed account of Mr. Taylor's experiments forms Appendix II. to this Report.

With regard to standards of *Capacity*, the Committee are able, thanks to the zealous co-operation of one of their number, to report somewhat more complete arrangements, Dr. Muirhead having undertaken for the present to make and issue Standard Condensers adjusted in accordance with one whose absolute capacity has been determined by himself and Mr. Hockin. ('Brit. Assoc. Rep.,' 1879, pp. 283 and 285.)

With a view to testing the permanency of condensers made with mica, paraffined paper, or other solid insulators, Dr. Muirhead is also having constructed a large air-condenser.

In reference to the standard of *Electromotive Force*, the Committee have had to consider whether this ought to be based upon a particular combination of chemicals, forming a galvanic cell of definite electromotive force, such, for instance, as a Daniell's cell, constructed in a specified manner from materials of guaranteed purity, or the cell introduced by Mr. Latimer Clark ('Proc. Roy. Soc.' xx. 444), or whether they should not rather aim at the construction of some convenient form of electrometer capable of indicating with sufficient accuracy an electromotive force of about a volt. The first plan would be comparable with a supply of ice and boiling water as affording a standard interval of temperature; the second would be comparable with a thermometer showing the two limits of the standard interval.

The Committee are not yet prepared to make a final recommendation as to either method of embodying the standard electromotive force, though they are strongly inclined to believe that an electrometer or gauge, capable of showing when a definite electromotive force has been developed, by whatever means, will ultimately be found more satisfactory than any system in which the constancy of an electromotive force is inferred from the supposed constancy of the conditions under which it has been developed.

Another question of a more general kind, which, though it may not be of much immediate practical importance, will eventually have to be carefully considered, has occupied the attention of the Committee to some extent. It is the question as to what concrete standards should finally be recognised as fundamental standards. Supposing that we already had independent standards of *Resistance*, *Capacity*, *Electromotive Force*, *Quantity*, and *Current Strength*, each of them defined with all the accuracy that our present experimental methods admit of, they would infallibly be found to exhibit small discrepancies when compared together. For instance, the current of standard strength would not be exactly the same as that produced by the standard electromotive force acting in the circuit of the standard resistance, and we should then have to consider which of the three standards was to be corrected so as to bring it into harmony with the other two.

Similarly, in the case of the other electrical magnitudes. The known relations between these are sufficient to enable us to define the unit of any one of the five magnitudes just mentioned in terms of the units of any two of the rest. Hence it appears that the electrical standards of ultimate authority cannot be more than two in number, and it will have to be decided which pair of concrete standards are to be recognised as ultimate or fundamental, and what are to be left to be defined by reference to them.

A further question arising out of the mutual relations of the fundamental units was that of the magnitude of the practical units to which distinctive names should be attached. The present usage with respect to this matter is that a *resistance* of 10^9 C.G.S units is called an *Ohm*; an *electromotive force* of 10^8 C.G.S. units is called a *Volt*; and the current produced by a Volt acting through an Ohm, that is to say, a current of $10^8 \div 10^9$ or 0·1 C.G.S. unit is called a *Weber*. In the opinion of the Committee it was considered highly desirable, from a scientific point of view, that the relations among these standards should be simplified by defining them as follows:—

Ohm $= 10^9$ C.G.S. units of resistance.
Volt $= 10^9$ C.G.S. units of electromotive force.
Weber $= 1$ C.G.S. unit of current.

It was felt, however, that any recommendation involving a change in the value attached to terms which are rapidly coming into extensive use among practical electricians, might give rise to serious inconvenience. Therefore, although with regard to the scientific aspect of this proposal the Committee were decidedly in favour of the change, they felt that a public recommendation could not well be made until the practical inconveniences likely to follow had been very carefully investigated.

APPENDIX I.

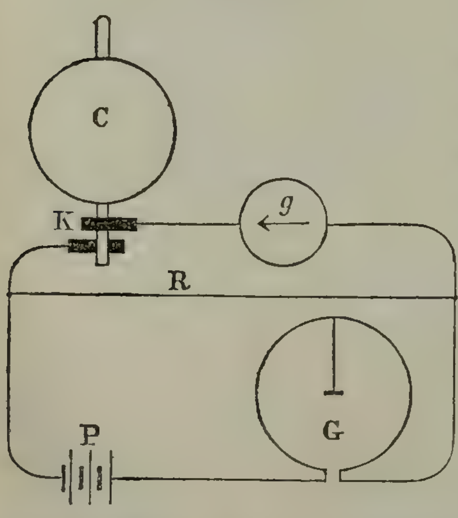
Account of Preliminary Experiments on the Determination of Electrical Resistances in Absolute Measure. By Professor G. CAREY FOSTER, *F.R.S.*

The experiments to be described in what follows were made in the Physical Laboratory of University College, London. The principle of the method employed is essentially the same as that of the method long ago pointed out by Sir William Thomson, and adopted by the first Committee of this Association upon Electrical Standards in their experiments of 1863 and 1864, as well as by Lord Rayleigh in the repetition of these experiments recently carried out by him in conjunction with Professor Schuster.

Every absolute measurement of resistance is, by the nature of the case, fundamentally the determination of the ratio of an electromotive force to the strength of the current which it produces in the conductor whose resistance is to be measured. In Sir William Thomson's method, as is well known, the electromotive force is due to the action of the earth's magnetism upon a coil of wire spinning about a vertical diameter, and its numerical value is known from the rate at which the coil spins, the total area enclosed by its windings, and the intensity of the horizontal component of the earth's magnetism. The electromotive force generates a current in the coil, the strength of which is known from the deflection of a small magnet, hung at the centre of the coil, and from the intensity of the earth's horizontal magnetic force. This last factor, entering similarly into the expressions for the electromotive force and for the current, disappears from their ratio, which gives in absolute measure the resistance of the wire forming the revolving coil.

In the method now to be described there is again an electromotive force generated in a revolving coil, just as in Sir William Thomson's method, but the current is measured by an independent galvanometer, and the conductor, whose resistance is given by the experiments, is entirely distinct from the revolving coil. So far as this method possesses any particular advantages they arise from the circumstance last mentioned. The conductor of which the resistance is measured being at rest, it may be a coil of wire of any material, wound in whatever way may be most convenient; and it may be immersed in a bath of liquid so as to keep it at an accurately known temperature. Moreover, several independent coils of different resistances can be experimented upon one after another, and the resistance of each determined.

FIG. 1.



The nature of the method and the arrangement of the essential parts of the apparatus may be explained by help of the adjoining figure. In this, R stands for the *wire*, of which the resistance is to be measured; and P for a *thermopile* whereby a current is produced through R and through a *tangent-galvanometer* G. The ends of the wire of the revolving coil C are connected, through a commutator K upon the axle, with the ends of the wire R, a delicate reflecting galvanometer g, called in what follows the *zero-galvanometer*, being interposed on one side of the commutator. When the speed of the coil is so adjusted that the zero-galvanometer is not deflected, the electromotive force developed in the coil by the magnetism of the earth is equal to the electromotive force exerted by the thermopile between the ends of the conductor R. Consequently, the resistance of this conductor is obtained in absolute measure by dividing the electromotive force of the coil by the strength of the current indicated by the tangent-galvanometer.

This result may be expressed in terms of the experimental data, as follows. Let A be the total area included by all the convolutions of the revolving coil—that is, the sum of the areas included by all the turns taken severally, H_c the horizontal magnetic intensity at the place occupied by the coil, ω the angular velocity of the coil, and $2a$ the arc of contact made by the commutator, then E, the electromotive force of the coil, is

$$E = H_c A \omega \frac{\sin a}{a}$$

Again, if Γ is the strength of the magnetic field produced at the centre of the tangent-galvanometer, where the needle is hung, by a current of unit strength flowing through the galvanometer, H_G the horizontal intensity of the earth's magnetic field at the same point, and θ the deflection of the galvanometer, the strength C of the current in the galvanometer, and therefore also in the wire R, is

$$C = \frac{H_G}{\Gamma} \tan \theta.$$

Hence, putting ρ for the resistance to be measured, that of the wire R, we have

$$\rho = \frac{E}{C} = \frac{H_c A \omega \Gamma \frac{\sin a}{a}}{H_G \tan \theta}$$

or

$$\rho = \frac{H_c}{H_G} \cdot \frac{2\pi A \Gamma \frac{\sin a}{a}}{T \tan \theta}$$

if T is the period of one revolution of the coil.

If the experiment could be made in a region of uniform magnetic force, we should have $H_c = H_G$, and therefore the ratio $\frac{H_c}{H_G} = 1$, as in Sir William Thomson's method. Owing to the neighbourhood of rather large masses of iron, this condition was not fulfilled in the actual experiments. The ratio in question was accordingly determined by noting the time of vibration of the same magnet when it was suspended alternately in the position of the revolving coil and in that of the galvanometer respectively. It was thus found at the beginning of the experiments that $\frac{H_c}{H_G}$ was equal to 0·9889. A repetition of the measurement that was afterwards attempted was made useless by some large masses of iron being brought just outside the Laboratory while it was going on.

The ring upon which the revolving coil was wound, as well as the frame in which it was mounted, were in the main copied from those used in the experiments of the former Committee, but both ring and frame were made considerably stouter in the metal, and the ring had only one groove instead of two. The upper and lower halves were insulated from each other, to prevent the formation of induced currents.

To determine the area A, we have $A = n m^2/4\pi$, where n is the number of turns of wire on the coil and m the circumference of the mean layer. The value of m was ascertained by measuring with a steel tape the circumference of the groove in which the coil was wound, as well as the circumference after each successive layer of wire had been put on. The mean of all these measures, corrected for the thickness of the tape, about 0·01 cm., was taken as the value of m. In order to guard against accidental error, the separate measurements of the circumference were combined in pairs, thus $m_o + m_n, m_1 + m_{n-1}, \ldots$ the suffixes denoting the numbers of layers of wire which had been wrapped on when the several measurements were made; these sums, which ought to be constant, varied between 193·25 cm. and 193·50 cm., the number of layers being 32. In this way the circumference of the mean layer was found to be 96·669 cm. which gives for the area enclosed by it 743·66 sq. cm. Each layer of wire contained 30 turns, and therefore $n = 30 \times 32 = 960$, and the total effective area of the coil was $A = 960 \times 743{\cdot}66 = 713914$ sq. cm.

The tangent-galvanometer had two equal parallel coils, of approximately square section, placed at a distance apart nearly equal to their mean radius, which was about 18·25 cm. Each coil consisted of 22 layers of 20 turns each; the galvanometer had thus altogether 880 turns of wire. The needle consisted of three short bits of hardened and magnetised watch-spring, fastened one above another at the back of a light plane-glass mirror. The deflections were read upon a straight glass scale, divided at the back into millimetres. The distance from mirror to scale was 137·25 cm., of which about ·45 cm. was occupied by glass; the optical distance was therefore taken as 136·95 cm. The galvanometer-constant Γ was calculated by the formula

$$\Gamma = \frac{4\pi n}{s+s'}\left(b_1 \; log_e \frac{a_1 + \sqrt{a_1^2 + b_1^2}}{a_2 + \sqrt{a_2^2 + b_1^2}} - b_2 \; log_e \frac{a_1 + \sqrt{a_1^2 + b_2^2}}{a_2 + \sqrt{a_2^2 + b_2^2}}\right)$$

where n is the number of turns of wire (880) in the two rings taken together, s and s' the areas of the cross-sections of the two coils, a_1 the external radius of each coil, a_2 the internal radius, b_1 the half-distance measured parallel to the axis between the outer surfaces of the coils, and b_2 the half-distance between their inner surfaces. The numerical values were $a_1 = 18{\cdot}945$ for one coil, $= 18{\cdot}953$ for the other; $a_2 = 17{\cdot}518$ and 17·524; $b_1 = 9{\cdot}851$, and $b_2 = 8{\cdot}429$, all in centimetres. The values for a_1 and also for a_2 being so nearly alike for the two coils, the means $a_1 = 18{\cdot}949$ and $a_2 = 17{\cdot}521$ were used in the calculation of Γ. The numerical value of Γ was thus found to be 1/0·004618, so that the absolute strength of a current measured upon this galvanometer is

$$0{\cdot}004618 \text{ H} \tan \theta.$$

The commutator of the revolving coil consisted of a cylindrical piece of ivory about 7·6 cm. in diameter, with two pieces of platinum let in upon opposite sides. One end of the wire was fastened to one of these platinum pieces and the other end to the other piece; and contact with the external circuit was made through two platinum-faced gun-metal wheels, each about 15 cm. diameter, which revolved in contact with the ivory cylinder. The wheels revolved in insulated bearings about vertical axes, nearly in the same plane as the axis of rotation of the coil. The upper end of the axle of each wheel carried a small copper mercury-cup into which a well-amalgamated copper wire dipped for connecting the coil with the end of the wire R (see figure), of which the resistance was to be measured. This arrangement was adopted in order to avoid the heating, and consequent thermo-electric action, which would probably have resulted from the use of rubbing contacts. It was found very efficient for this purpose.

In order to avoid as far as possible the effects of self-induction in the revolving coil, the platinum contact-pieces had an angular breadth of only about 20 degrees, so that the coil was in metallic connection with the rest of the circuit during only about $\frac{1}{9}$th of each revolution. By adjusting the contact-wheels so that the vertical plane containing their axes coincided with the magnetic meridian, the middle of the period of contact was made to coincide with the instant of maximum intensity and minimum rate of variation of the electromotive force in the coil. The arc of contact actually employed was 20° 3′, which gives for the ratio of the maximum and minimum electromotive force due to the earth's magnetism the value 1 : 0·9817, or an extreme variation of less than 2 per cent.

Putting together the values of the constant factors in the expression for the resistance to be determined, we get

$$\rho = \frac{9{\cdot}5561 \times 10^8}{\mathrm{T} \tan \theta},$$

leaving T, the period of rotation of the coil, and θ, the deflection of the tangent-galvanometer, to be observed in each experiment.

To determine the speed of the coil, the following method was adopted. Three glass pens, each controlled by a small electro-magnet, were caused to mark side by side upon a strip of paper drawn forward by clockwork, as in an ordinary Morse receiver. The pens, when left to themselves, ruled parallel straight lines on the paper, but when any of the electro-magnets was excited, the corresponding pen was pulled to one side and a notch was made in the line the pen was drawing. By means of a wheel of 100 teeth, carrying a pin which made contact with a light spring once in every revolution, and gearing into a screw cut upon the upper part of the axle of the coil, the circuit of one of the electro-magnets was completed for an instant at every hundredth revolution of the coil, and an indentation was made in the corresponding line. The circuit of the second electro-magnet was broken for an instant by a clock at intervals of one second, thus making notches on the second line. By afterwards measuring the distances between the notches on the two lines, the speed with which the coil was spinning at any instant could be ascertained. This measurement was made by laying over the paper a strip of glass divided on its lower surface into centimetres and millimetres. The degree of accuracy attainable in this way, independently of error of the clock, was about one part in one thousand. The speeds used in the experiments varied from about nine to about twelve revolutions per second. The electro-magnet acting on the third pen was under the control of an observer who watched the zero-galvanometer (g in the figure,) and held down a contact-key, which completed the corresponding circuit whenever and as long as this galvanometer showed no deflection. In this way the third line on the recording strip was displaced to one side whenever the speed was such as to cause the electromotive force of the coil and that due to the thermo-electric pile accurately to balance each other, and thus the parts which were to be measured of the other two lines were indicated. A second observer noted the reading of the tangent-galvanometer when the zero galvanometer was undeflected, and thus determined the angle θ.

It is evident, from the formula given above, that the product T *tan* θ should be constant in all experiments in which the wire whose resistance was to be determined was the same. The amount of agreement in the value of this product in different experiments therefore affords a criterion of the consistency of the results with each other. The results obtained in two series of experiments were as follows:—

T *tan* θ (Series I.)	T *tan* θ (Series II.)
0·01291	0·01192
·01296	·01196
·01309	·01194
·01312	·01196
·01309	·01189
·01283	·01192
·01298	·01193
·01306	·01194
·01295	—
·01306	—
·01302	—
·01294	—
·01310	—

It will be seen that the second set of values agree better together than the first set. This is probably chiefly due to greater practice in observing, and to the adoption of an artifice whereby the speed of the gas engine employed to drive the coil was kept more constant. In calculating the final result from each set, weight was given to each separate observation in proportion to the square of the number of revolutions of the coil over which it extended; for it was assumed that the accuracy with which the speed of the coil was determined was proportional to the number of revolutions included in the record; moreover, the number of galvanometer-readings obtained in each experiment was proportional also to the number of revolutions, and hence it was assumed that the accuracy with which the product was determined was proportional to the square of the number of revolutions. The weighted means thus calculated are, for the

First series .	0·013017
Second series .	·011932

Calling ρ_1 and ρ_2 the resistances measured in the two series of experiments respectively, these results give

$$\rho_1 = \frac{9{\cdot}5561}{{\cdot}013017} \times 10^8 = 73{\cdot}412 \times 10^9,$$

$$\text{and } \rho_2 = \frac{9{\cdot}5561}{{\cdot}011932} \times 10^8 = 80{\cdot}089 \times 10^9.$$

The wires measured belonged to a set of german-silver resistance-coils, which were very carefully adjusted by my assistant, Mr. W. Grant, by comparison with a 'B. A.-unit' coil issued by the former Committee. The nominal values were 73 and 80 ohms in the two sets of experiments respectively. Applying a not very certain correction for the difference between the temperature of the coils during these experiments and that at which they were adjusted, we get for the nominal values

$$\rho_1 = 73{\cdot}16 \text{ ohms} \quad \text{and} \quad \rho_2 = 80{\cdot}18 \text{ ohms}.$$

Hence, according to the *first* series of experiments,

$$1 \text{ ohm} = \frac{73{\cdot}412}{73{\cdot}16} \times 10^9 = 1{\cdot}003 \times 10^9;$$

according to *second* series

$$1 \text{ ohm} = \frac{80{\cdot}089}{80{\cdot}18} \times 10^9 = 0{\cdot}999 \times 10^9.$$

I do not attach any particular importance to these values, or to the close agreement of their mean with the intended value of the ohm, as the experiments, so far, have only been undertaken with the view of ascertaining how far the method that has been described is capable, when employed under favourable circumstances, of giving good results. In this respect I think the experiments may be considered fairly satisfactory, but the numbers obtained for the value of the ohm are subject to several corrections, the most important of which are probably that for errors of the clock, which I had no means of rating more accurately than by comparison with a good watch; that due to slight uncertainty as to the value in ohms of the resistances measured; that due to self-induction in the revolving coil, which, however, I believe must be very small; and perhaps errors due to unobserved disturbances of the magnetic field during the experiments.

I wish, in conclusion, to acknowledge with warm thanks the obligations I am under to Mr. Charles Hockin for most valuable aid of various kinds,—important practical suggestions as to the construction of the apparatus, information as to the conditions required in order to ensure sensitiveness, and the loan, for a long time, of a very delicate zero-galvanometer and a set of resistance coils. I am also greatly indebted to Mr. Grant and Mr. G. W. von Tunzelmann, B.Sc., by whom conjointly the actual observations were almost entirely made.

Appendix II.

On the Causes of the Variation in the Temperature-Coefficient of the Alloys of Platinum and Silver. By Herbert Taylor, Esq.

In his report to the Committee of the British Association in 1862 Dr. Matthiessen proposed for the construction of standard resistance coils the now widely-used alloy of silver and platinum, consisting of two parts of silver and one part of platinum by weight. In the same paper he gave the specific conducting power of the material and also its percentage-variation in resistance due to a change of temperature of 1° centigrade.

The latter value, called the temperature-coefficient in what follows, he stated to be 0·031% per degree.

It was, however, found, after the alloy came into general use, that the temperature-coefficient varied within moderately wide limits.

And it was noticed, by the writer amongst others, that having determined by experiment the coefficient of a particular wire, it was necessary to make a fresh determination for the same wire when drawn down to a finer gauge.

An investigation into the causes of these variations was therefore desirable; and at the request of your Committee it has been undertaken by myself. As yet, no very definite result has been reached, but the observations already made, involving much care and a very large expenditure of time, and the method of experimenting employed, may perhaps be worth recording.

I should here say that throughout the investigation I have had the benefit of the co-operation of Mr. Charles Hockin, by whom many of the observations were made.

To better observe the variation in the temperature-coefficient with change of diameter, rods of considerable sectional area, to be afterwards drawn into wire, were obtained from Messrs. Johnson & Matthey.

The first rod (called hereafter Bar A) was of the commercial alloy manufactured specially for electrical purposes; the metals used are commercially pure, and are melted together in large quantities. The alloy is then cast as a flat ingot, not more than an inch or an inch and a half in depth, and this ingot is next rolled into a large sheet about 0·3 inch thick, which is cut by shears into narrow strips.

These strips are finally passed between grooved rollers, to give them an approximately circular section, and the rods thus formed are ready for the draw plates to reduce them to wire of the required diameter.

The bar experimented on was, in the 'rod' stage, about 8 inches long, and 0·27 inch in diameter.

The second rod (called hereafter Bar B) was specially made for these experiments of pure materials, by Messrs. Johnson and Matthey.

It was cast in the form of a bar, about 8 inches long. On leaving the mould it was about 0·3 inch square, slightly tapering, and more or less irregular in section, but was reduced in the lathe and by filing to a section almost absolutely square and uniform.

The third rod (called Bar C) was of an alloy made by the same firm for the use of dentists—the method of casting and rolling being the same as that described for the electrical alloy, but rather less attention is paid to the purity of the components.

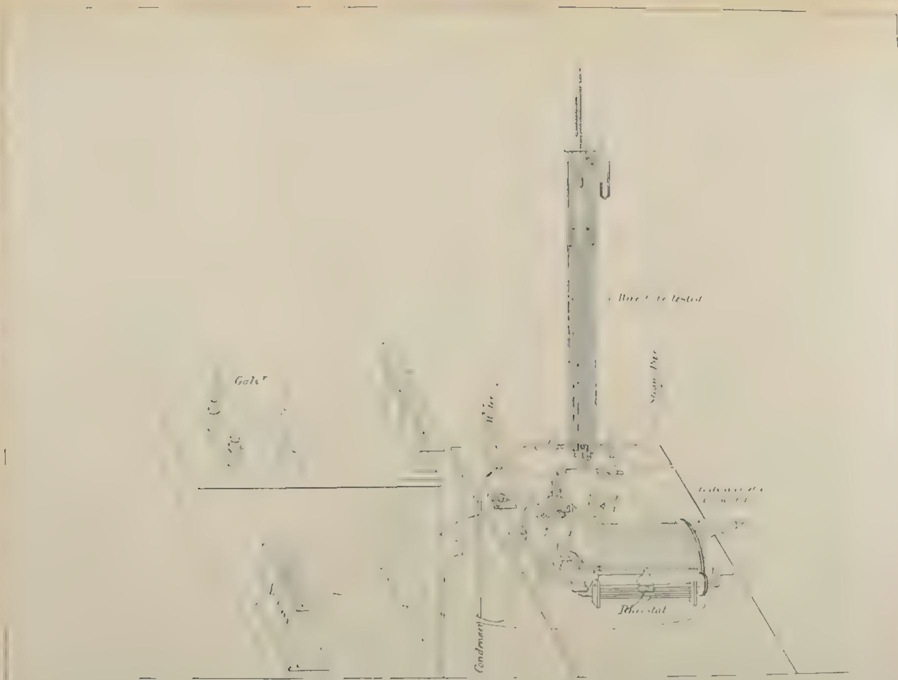
It was procured in the form of a narrow strip, about a quarter of an inch thick, and reduced to a uniform square section by the lathe and file.

As it was necessary to observe accurately the small percentage-variation, due to change of temperature, in the resistance of these bars, which was itself exceedingly minute, recourse was had to the method of observation originally proposed by Mr. C. Hockin, and described and figured in Clerk Maxwell's 'Electricity and Magnetism,' pp. 406 and 407, vol. 1, by means of which the unavoidable resistance of the connections can be altogether eliminated.

Instead, however, of using, as shown in the figure referred to, a comparatively short wire, with resistance-bobbins at its ends, a wire 40 feet in length, wound on a cylinder, was employed, so that the bobbins could be dispensed with, without loss of accuracy, and with a great gain in simplicity of calculation and in range.

To avoid the very great expense of a necessarily thick wire of iridio-platinum, which was, however, recognised to be the best material, a german-silver wire was in the first instance fitted to the cylinder and calibrated, but after a short time it was found to get loose in its groove, so that the readings obtained on it could not be depended on.

A platinum-silver wire was next tried, and though most carefully



APPARATUS FOR DETERMINING TEMPERATURE COEFFICIENT OF WIRES

Illustrating the Report of the Committee for constructing and issuing practical standards for use in Electrical Measurements drawn, the calibration showed such a want of uniformity in the conducting power at different parts of its length that it was at once discarded.

Finally, an iridio-platinum wire was obtained from Messrs. Johnson and Matthey, fitted to the cylinder and calibrated, but the result not being considered quite satisfactory, the wire was removed, carefully annealed, drawn through one hole in a draw plate and remounted, but with very little better results. This operation was repeated without advantage, and it became evident that the want of uniformity in the conducting power was not due to irregularities in the section of the wire, but was to be attributed, in all probability, to want of uniformity in the composition of the alloy.

To avoid further loss of time it was therefore decided to make use of the wire as it then was, and to correct all readings by the result of an accurate and close calibration.

The wire was therefore calibrated in 100 equal parts by a method devised after trying one or two others, and found to be very accurate and convenient.

It is fully described at the end of this paper.

The wire is wound in twenty convolutions in a spiral groove, accurately formed in the cylindrical surface of an insulating drum. The ends of the wire are soldered to massive bars, each brazed to one axle of the drum, which terminates in an amalgamated copper disc, half immersed in a cup of mercury.

The mercury cups are themselves connected with the rest of the apparatus by means of very stout copper rods.

The contact-piece, by means of which the galvanometer is put in circuit, is mounted on a brass block, moving between two brass rods, and traversed by a screw after the fashion of the slide rest of a lathe. One end of the screw carries a toothed wheel, gearing with another wheel attached to the drum and concentric with it. The pitch of the screw and the gearing are so calculated that, when the drum is made to revolve, the contact-piece, whilst moving in a horizontal line parallel with the axis of the drum, is always in contact with some point of the wire, upon which it presses lightly by means of a spring.

The brass toothed wheel has a slightly greater diameter than the drum to which it is attached. On the flat exterior side near its circumference, it is divided into 1,000 equal parts, and by means of a microscope with cross-wire eyepiece, the divisions can be read by estimation to tenths and easily to fifths.

As there are twenty turns, the whole wire can therefore be accurately divided into 100,000 parts.

Whole turns of the wire are shown by the divisions of a horizontal scale close to the contact-piece.

To maintain the wire throughout its length at a uniform temperature, the drum is enclosed in a wooden case in which openings are left for the contact-piece and microscope. A sketch of the apparatus is given in Plate VI.

To determine the temperature-coefficients of the various bars and wires, their resistances at two different temperatures were compared with that of a standard, maintained as nearly as possible at a constant temperature.

The higher temperature of comparison was generally nearly that of boiling water, and was maintained by means of steam. The bars were immersed in a bath of melted paraffin wax, the interior surface of the bath being lined throughout with convolutions of $\frac{1}{4}$ inch 'compo' gas-tubing through which steam was caused to flow.

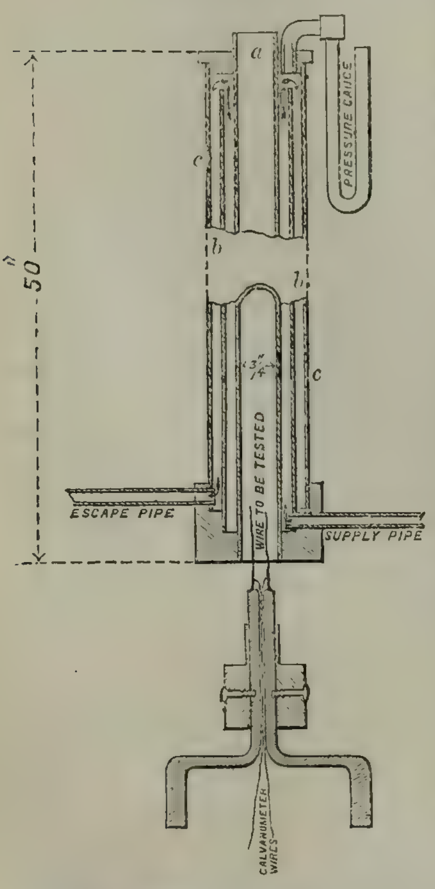
The lower temperature was about that of the air, the bath just described was again used; but paraffin oil was substituted for the wax, and cold water from the main was made to circulate in the pipe instead of steam. In both cases the paraffin oil or wax was kept continually stirred. The standard was also immersed in paraffin oil, kept at a uniform temperature by the circulation of water from the main, through tubing in the containing vessel.

The paraffin oil used possesses remarkably high insulating qualities, bobbins of silk-covered wire, even of many thousand ohms resistance, could be immersed in it, without the least sensible leakage, from spire to spire. It is sold under the name of 'Strange's Crystal Oil.'

The apparatus for maintaining the desired temperature when the alloy is in the form of wire is far more convenient than that described above for the bars. It resembles the instrument used for testing the boiling point of thermometers.

It is shown in section in the accompanying sketch, fig. 2.

FIG. 2.



a is an open tube about $\frac{3}{4}$-inch in diameter, surrounded by a second tube, *b*, closed at the bottom and opening at the top into the outer tube, *c*, which is closed at both ends. The supply pipe leads into the annular space between *a* and *b*, near the bottom, and the exhaust, or escape, pipe from the space between *b* and *c*.

When steam is allowed to enter by the supply pipe, it completely envelopes, in its passage, the inner tube *a*, and external influences, such as sudden draughts of air, are effectually cut off by the steam jacket between *b* and *c*. For observations at ordinary temperatures water is allowed to flow into the supply pipe instead of steam, and a convenient system of pipes and cocks allows the change to be made from steam to water, or *vice versâ*, with facility. When steam is used, a mercurial gauge is provided, to indicate the difference of pressure between the inside of the tube and the atmosphere.

The temperature calculated from the reading of this gauge, and that of the barometer, was found to agree within $\frac{1}{10}$ degree with the indication of the thermometer inserted in the inner tube *a*.

The bottom of the inner tube *a* is closed by an ebonite stopper, through which pass two stout copper rods of semicircular section, so as to have the greatest available cross section; each is held rigidly in position by a screw passing radially through the ebonite stopper, and they are insulated one from the other by an air space, through which pass the wires for the galvanometer connections, the interstices being afterwards filled with shellac.

The ends of the wire to be tested are soldered to the upper extremities of the copper rods. When the wire is short and thick, it is covered with silk, bent double, and passed into the tube; when thin, it is wound on a glass rod, and the whole coated with silk ribbon. The space between the wire and tube is filled with lead shot of the smallest size, and a thermometer is inserted in the top of the tube, which is then filled quite up with shot.

It was found that the shot had an exellent effect in preventing minute oscillations of temperature, due to draughts or similar causes.

The battery used was one large Grove cell; the galvanometer, a 'dead beat' by White, having a resistance of 1·4 ohms.

In most cases the absolute resistance of the specimens of alloy was determined as well as the temperature-coefficient.

For the bars this was done by comparison with a rod of pure lead of known dimensions.

The wires were compared directly with bobbins of known resistance.

The sectional area of the bars and wires was always calculated from their weight, specific gravity, and length.

All bars and wires were annealed before making the electrical observations.

The following table shows the resistance and temperature-coefficient of the first sample of the alloy when in the original bar shape, and when drawn down to wire of various gauges.

Bar A.

Length m.m.	Diameter m.m.	Resistance of a wire 1 metre long and 1 millimetre diameter at 0° Cent.	Specific gravity	Percentage-variation in resistance for 1° Cent.	Remarks
		ohms.			
175·67	6·825	0·3658	12·740	·0299	Rod
996·40	1·578	0·3824	12·733	·0276	
3132·70	0·525	—	12·613	·0273	
2655·25	0·525	0 3937	12·811	·0263	
—	0·203	—	—	·0232	
—	0·168	—	—	·0231	

A complete analysis of this alloy from the end of the rod was made for me by Messrs. Johnson and Matthey. The composition was as follows:

Platinum	32·95
Silver	66·65
Iridium	0·03
Rhodium	0·01
Iron	0·01
Lead, with minute trace of copper	0·01
Loss	0·34
	100·00

The platinum and silver are thus very nearly in the prescribed proportion, and the amount of impurity is inconsiderable. An assay of a piece cut from one end of the wire 1·578 m.m. in diameter, gave the proportion of platinum as 31·34 %.

A calibration made from inch to inch in its length showed the conducting power to be sensibly uniform.

Bar B.

The temperature-coefficient of this bar was 0·0308%. The specific gravity and absolute resistance were abnormal, and a calibration showed it was quite irregular in conducting power, the casting being porous and full of holes.

Messrs. Johnson and Matthey failed in their attempt to roll or draw it down into wire, but a small portion was remelted and drawn into wire 0·67 m.m. in diameter, of which the specific gravity was 13·354, the temperature-coefficient ·0282%, and the calculated resistance of 1 metre of the wire, 1 millimetre in diameter, 0·238 ohms. It was obvious, therefore, that even if the alloy was of the desired composition, on the average, it had such a want of uniformity that an analysis was not worth making.

Bar C (dental alloy).

The following Table gives the observations made with this sample of alloy from the bar stage to that of very fine wire.

Length m.m.	Diameter m.m.	Resistance of a wire 1 metre long and 1 m.m. in diameter	Specific gravity	Percentage-variation in resistance for 1° Cent.	Remarks
		ohms.			
168·00	4·314	0·3770	12·444	·0269	Square bar
996·95	1·625	0·3611	12·449	·0261	
2416·15	0·535	0·3690	12·630	·0266	
—	0·203	—	—	·0248	

Messrs. Johnson and Matthey's analysis of this alloy was as follows :—

Platinum	28·95
Silver	70·50
Rhodium	0·01
Iridium	0·02
Iron	0·02
Lead, with minute traces of copper and loss	0·50
	100·00

An assay of one end of the wire of the diameter 1·625 m.m. gave 28·44 % as the proportion of platinum; but it would appear, from the third observation of specific gravity in the above table, that the composition could not be uniform—indeed the bar was calibrated in six parts, both at the high and low temperature, and the temperature-coefficients for the different parts were found to be as follows: ·028, ·032, ·029, ·036, 0·031, and 0·029 per cent. per degree.

To examine the effect on the temperature-coefficient of a variation in the percentage of platinum and silver, the following alloys were cast by Mr. Hockin and drawn to wire. They were made with pure platinum, black and precipitated silver.

Composition of alloy		Diameter approximate	Percentage-variation in resistance for 1° Cent.	Remarks
Pt %	Ag %	m.m.		
40	60	0·234	·0259	
$33\frac{1}{3}$	$66\frac{2}{3}$	0·096	·0265	} different castings
$33\frac{1}{3}$	$66\frac{2}{3}$	0·234	·0301	} different castings
30	70	0·234	·0313	
25	75	0·234	·0407	
25	75	0·063	·0377	

From the foregoing tables it would appear that a moderate variation in the percentage-composition on either side of the normal proportions of two parts silver, by weight, to one part platinum, produces less effect on the temperature-coefficient than does a change in the diameter of the wire.

It also appears, from these and other experiments, that it is practically impossible to ensure a uniform mixture of the metals, even when the alloy is of the normal composition in the aggregate.

Thus the wire from an unit coil of the B.A. pattern, made by Dr. Matthiessen, or under his superintendence, was drawn down to a diameter of 0·168 m.m.

The whole wire had a temperature-coefficient of ·0250%, but on examining the wire in two approximately equal portions, the temperature coefficients of the two halves were found to be ·0237 and ·0266%.

It is therefore evident that when the highest attainable accuracy is acquired, as in the construction of standard coils, it is not sufficient to depend upon the general temperature-coefficient of the alloy, but that a determination of the coefficient of the particular coil or instrument is required.

For less accurate work it would seem that Dr. Matthiessen's value for the coefficient, viz., ·031% per 1° C. should be reduced by from 5 to 10% for wires of large diameter, by about 15% for wires of 0·25 m.m. diameter, such as, in general, resistance-coils of from 100 to 1,000 ohms are made of, and by from 20 to 25% for wires of the smallest gauge usually drawn.

Calibration of Wire.

The calibration of the wire was effected thus—Six coils of the B.A. pattern, viz., 1*a*, 1*b*, 2, 3, 5, and 8 ohms, whose resistance amounted, in the aggregate, to 20 ohms, were arranged in a continued series by means of mercury cups, and the ends of this series were connected by copper bars with the two ends of the wire to be calibrated, properly mounted on its drum. To these copper bars the poles of the battery could be connected by means of a contact-key.

The series of coils was arranged, in the order above enumerated, in a trough of water, to maintain uniform temperature. One galvanometer wire was permanently attached to the sliding contact of the drum, whilst the loose end of the other galvanometer wire could be dipped in either of the mercury cups joining the coils, the arrangement thus forming a Wheatstone's bridge.

The loose galvanometer wire, being first inserted in the mercury cup joining the outer or left-hand terminal of the coil 1a with the connecting bar, a balance was obtained, the reading r_0 on the drum being of course quite close to the 0 end of the wire.

The galvanometer wire was then shifted to the cup between 1a and 1b, and a balance and reading r_1 obtained by moving the drum-contact.

The coils 1a and 1b were then transposed in position, and a new balance and reading r_2, very near to r_1, were obtained. The loose wire was then moved to the cup between 1a and 2, and the balance and reading r_3 were observed.

This process of transposition and reading was repeated until the coil 1a had been moved unit by unit from the left-hand to the right-hand extremity of the series.

As it is evident that the resistance of the length of wire between pairs of readings such as r_0, r_1, and r_2, r_3, &c., bears the same ratio to that of the whole wire to be calibrated as the resistance of the coil 1a does to that of the series of which it forms part, and that the latter ratio is a constant one, being independent of the position in the series which the coil occupies, it follows that every such length has the same resistance; and the lengths being expressed in terms of divisions of the drum circle, it is easy to make a table showing the proper corrections.

In practice, the coil 1a was further subdivided. Four intermediate points having been determined on the wire of which it was composed, dividing its resistance into five equal parts, wires were soldered to these points and were connected with small mercury cups sunk in the ebonite bridge-piece of the coil. The case was then filled in with paraffin wax as usual. In calibrating the drum-wire, therefore, besides the 20 pairs of readings corresponding with the 20 transpositions of the coil, there were interpolated between each such pair four additional readings, thus calibrating the wire into 100 parts.

The following table gives the readings corresponding to the twenty transpositions of the coil, their differences, which are proportional to the conducting power of the wire between the points at which the readings are taken, and the percentage-variation from mean conducting power.

In Col. IV. are given the total percentage-corrections for the readings in Col. V. They are obtained by taking from Col. III. the algebraic sum of the percentage-variations for all observations included in the reading, and dividing by the number of terms summed; thus the correction for drum-reading 3,000, and thereabouts is $\frac{1{\cdot}015 + 0{\cdot}835 + 0{\cdot}513}{3{\cdot}}$ $= 0{\cdot}788\%$ of the readings. All these corrections happen to be subtractive.

I. Observed readings	II. Differences of readings proportional to Conductivity	III. Percentage-variation from mean Conductivity.	IV. Percentage-corrections for Readings in Col. V.	V. Readings.
3·3				
1009·1	1005·8	+ 1·015	1·015	1000
1012·9				
2016·9	1004·0	+ 0·835	0·925	2000
2020·2				
3021·0	1000·8	+ 0·513	0·788	3000
3025·5				
4024·9	999·4	+ 0·373	0·684	4000
4028·6				
5027·5	998·9	+ 0·322	0·612	5000
5031·1				
6030·4	999·3	+ 0·363	0·570	6000
6034·2				
7033·9	999·7	+ 0·403	0·546	7000
7039·8				
8034·9	995·1	− 0·059	0·471	8000
8038·7				
9037·3	998·6	+ 0·292	0·451	9000
9041·8				
10037·1	995·3	− 0·039	0·402	10000
10040·7				
11034·1	993·4	− 0·230	0·344	11000
11038·0				
12033·7	995·7	+ 0·001	0·316	12000
12033·6				
13028·8	995·2	− 0·049	0·288	13000
13032 3				
14026·6	994·3	− 0·140	0·257	14000
14030·4				
15022·0	991·6	− 0·411	0·213	15000
15027·6				
16017·9	990·3	− 0·541	0·166	16000
16022·4				
17011·0	988·6	− 0·712	0·114	17000
17014·9				
18006·4	991·5	− 0·421	0·084	18000
18010·0				
19000·0	990·0	− 0·571	0·049	19000
19003·7				
19990·0	986·3	− 0·943	0·000	20000
Mean	995·69			

It is of course unnecessary that the subdivisions of the 1-ohm coil should be exactly equal, provided their ratio is known, and this can easily be found by the drum-wire itself. Thus the coil is substituted for the series of 20 ohms, before referred to, and the readings observed on the drum when galvanometer connection is made consecutively at the six contact-points of the divided coil. These observations will coincide very nearly with readings in the foregoing table which are independent of the subdivisions of the coil. Therefore, by applying the proper tabular corrections, the true ratio of these subdivisions is determined.

On some New Theorems on Curves of double Curvature. *By* Professor STURM.

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

THE following theorems on curves of double curvature are the result of my study of the very interesting papers on twisted curves of the fifth order, which Professor Cayley has published in the 'Comptes Rendus,' vol. liv. and lviii. (1862, 1864). Cayley there considers monoids of the order m with a given vertex or summit, and passing through a given curve of double curvature; that is to say, surfaces of the order m, passing through the curve, and having, at a given point O, a multiple point of the degree $m-1$ of multiplicity. The cone of the order $m-1$, generated by the right lines which have, in common with the surface at this point, m coincident points, contains all lines passing through O, and meeting the curve twice. With reference to these lines or chords, and to their mutual dependence, the consideration of the above-mentioned cone has led me to some new results.

1. Consider a curve of the nth order, without singular points, to which h chords proceed from a given point: let us term it a curve $[n, h]$. The maximum value of h is known to be $\frac{1}{2}(n-1)(n-2)$. Halphen has given,[1] without proof, the minimum value of h. Kohn, however, has published, in the 'Sitzungsberichte der Wiener Akademie,'[2] a demonstration of the same result, and last winter I also found this minimum value, before seeing the papers of Halphen and Kohn. This minimum value is the greatest integer contained in $\left(\frac{n-1}{2}\right)^2$, therefore $t(t-1)$, or t^2, according as n is equal to $2t$ or to $2t+1$. Curves with this minimum always exist; they are each situated on a surface of the second degree, and form, in the former case, its complete intersection with a surface of the order t, and, in the latter, when completed by a right line, its complete intersection with a surface of the order $t+1$.

2. Cayley has found that through every curve of the nth order a monoid of the $(n-1)$th order, with a given vertex, can be passed. Hence we infer that through the h chords which proceed from the given point, a cone of the order $n-2$ always passes. And if h has its maximum value, no cone of an inferior order can possibly contain all the chords; but if h diminishes, such cones become possible. There are certain values of h to be distinguished. I shall denote them by h_j, and define this symbol by the equation:

$$h_j = N(n-j) + \tfrac{1}{2}(j-2)(j-3);$$

where $t+1 \geq j \geq 3$, and $N(\nu)$ has the usual signification $\frac{1}{2}\nu(\nu+3)$. The most important of these values seems to be $h_4 = \frac{1}{2}(n-2)(n-3)$, a fact with which M. Halphen, I understand, is well acquainted. We have, moreover, $h_3 = \frac{1}{2}(n-1)(n-2) - 1$.

When h becomes $\leq h_j$, cones of the order $n-j$ through the h chords are possible, and the degree of their manifoldness is always $h_j - h$; j being > 3, the chords are so related to each other that every cone of the order $n-j$, passing through any $h - \frac{1}{2}(j-2)(j-3)$ of them, contains also the remaining ones. I was surprised when I first detected this relation in a special case, viz. the known intersection of a surface of the

[1] *Comptes Rendus,* vol. lxx. (1870). [2] October, 1880.

third with one of the second order, to which curve six chords proceed from an arbitrary point, all being situated on a cone of the second degree.[1]

Hence it follows, that, if $h \leq h_4$, a plane curve of the nth order with h double points is not necessarily the perspective of a twisted curve of this order with h apparent double points—a result with which M. Halphen also appears to be acquainted.

3. If, further, two cones of the orders m, m' be drawn through the h chords their $mm' - h$ remaining edges of intersection will be always situated on at least one cone of the order $v = m + m' - (n-1)$. If $h > h_4$, this is self-evident and without interest; it is not so in other cases, however, and I have found interesting theorems relating to the mutual dependence of these remaining edges of intersection and to the manifoldness of the cones of the order v which pass through them. I must not, however, attempt to communicate these theorems on this occasion.

4. We have seen that, if $h > h_4$, the h chords are independent of one another, so far as the conducting of cones through them is concerned. They cannot all be given arbitrarily, however; no more than can, in general, the double points of a plane curve when their number surpasses a certain limit. But I must not enter into this matter.

I will give a construction when $h \leq h_4$, of such a system of h rays issuing from a given point, as are formed by the h chords of a curve $[n, h]$. n and h being given, seek, first, that value of j which satisfies the condition

$$h_j > h \geqq h_{j+1};$$

then construct an arbitrary cone of the order $n - 2j + 1$, with its vertex at the given point; take, next, any $(n-j)^2 - h$ edges of this cone, and pass through them two cones of the order $n - j$; their remaining h edges of intersection will be rays of the required kind. The orders $n - 2j + 1$ and $n - j$ and the number $(n-j)^2 - h$ are so chosen, that, in general, neither of the last two cones breaks up, and that these cones have no further intersections on the first. I do not say that there always exists a curve, for which the h rays thus constructed are chords, or a cone, for which they are double edges; I say merely that the h rays in question have the same properties, with respect to cones passing through them, as have the h chords of a curve $[n, h]$. The degree of manifoldness of such a system of h rays issuing from a given point is

$$3h - (h_4 + 1); \; h \text{ being } \leq h_4.$$

5. But I was more interested in the degree of manifoldness of the curve $[n, h]$ itself in space, or—to use a phrase of Schubert's—the number of its constants, or, in other words, the number of simple conditions to which it can be submitted. I have, however, not yet succeeded with the general problem. I have once more found the result, for $h > h_4$, which Halphen has communicated, without demonstration, in the above-quoted paper in the 'Comptes Rendus'; viz., that if $h > h_4$, the number of conditions to which a curve $[n, h]$ can be subjected is always $4n$.[2] Brill and Noether have given[3] a lower limit for h. I have not yet found a connection between their reasoning and mine.

[1] Kohn seems to have given similar theorems; but an accurate comparison will soon show that his theorems are not only different from those above communicated, but for the most part self-evident and therefore without interest.

[2] Cf. also my remark in a paper published in *Crelle's Journal*, vol. lxxxviii.

[3] *Math. Ann.*, vol. vii.

The other case ($h \leq h_4$) is much more difficult. It is only when h has its minimum value that the problem can be easily solved, because the curve lies then on a surface of the second degree, and the h chords form the complete intersection of two cones. The number of conditions is, if $n = 2t$, $t^2 + 2t + 9$, or $t^2 + 2t + 8$, according as t is $>$ or $= 2$; and if $n = 2t + 1$, it is $t^2 + 3t + 10$, or $t^2 + 3t + 8$, according as t is $>$ or $= 1$.[1]

I repeat that I have not yet been able to find, for every such system of h rays as that constructed in Art. 4, a cone which has them for double edges.

6. By considering the monoids passing through a curve $[n, h]$, I have arrived at the following theorem:

The cone of lowest order passing through the h chords is of the degree $n - j$, j being defined by: $h_j \geq h > h_{j+1}$. Hence it follows that for a surface of the order $m > n - j$ to contain the entire curve will be a condition of the following degree of multiplicity:[2]

$$mn + 1 - \{\tfrac{1}{2}(n-1)(n-2) - h\} = mn + 1 - p.$$

Perhaps the inferior limit of m may be smaller, but certainly the theorem does not subsist in all cases.

7. I have approached the theory of twisted curves in another manner, by inquiring into the curves situated on a surface of the third order,—my old field of research. Following the example of Plücker, Cayley, and Chasles, who have considered the curves on a surface of the second degree,[3] I construct all curves on a given cubic surface by means of relations between the pencils of planes whose axes are two right lines of the surface, not situated in the same plane; in this manner I find 3, 6, 7, 11, 14 species of curves of the orders 5, 6, 7, 8, 9 respectively; on these I will make but two observations.

First, it often happens that two species agree in their order n as well as in the number h of their apparent double points, and hence also in their rank r, and in the degree of their manifoldness on the surface (which always is $\frac{1}{2}r$), but differ in the number of their intersections with the right lines of the surface. For instance, there are two curves of the sixth order with 10 apparent double points, and with the degree 5 of manifoldness on the surface: one of them meets 6 right lines 4 times, 15 twice, 6 not at all; the other meets 1, 1, 10, 5, 5, 5 lines, respectively, in 5, 4, 3, 2, 1, 0 points.

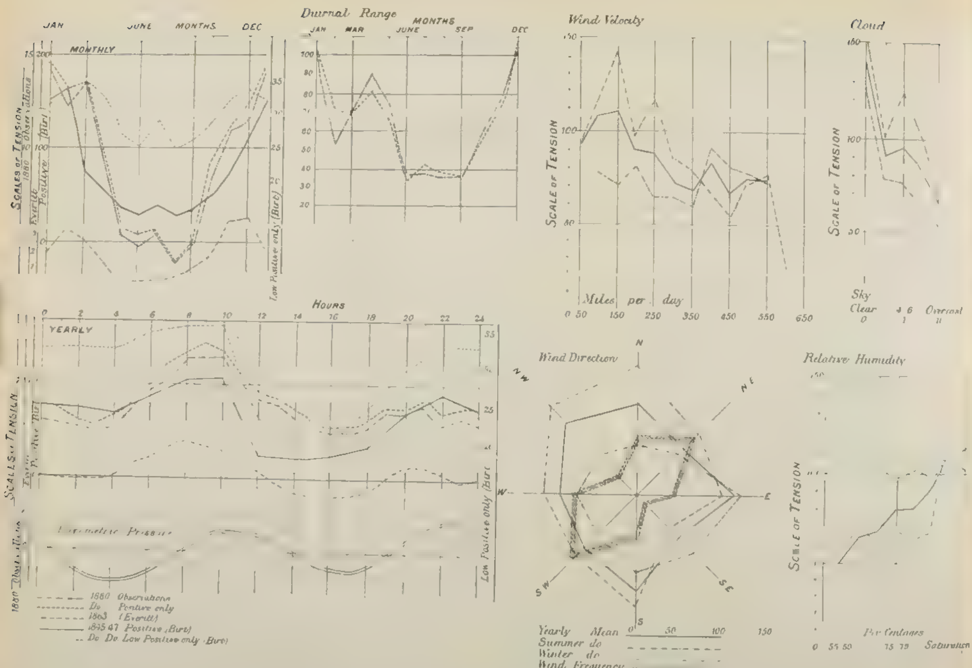
The second, and, in my estimation, the more important observation is, that most of these curves on a cubic surface are not general ones of their kind, that is to say, if we construct, on a cubic surface, all possible curves $[n, h]$, and then construct all possible cubic surfaces, we shall not reach the degree of manifoldness which is proper to a curve $[n, h]$. For instance, the curves $[9, 28]$ must have the degree 36 of manifoldness; but those situated on cubic surfaces have only the degree 27.

[1] Kohn also seeks these numbers, but makes an error in the first case.

[2] Ed. Weyr, in his papers on twisted curves of the sixth order (*Comptes Rendus*, vol. lxxvi.), appears to have overlooked the circumstance, that this condition is not necessarily of the degree $mn + 1$, and hence to have arrived at conclusions which are not all valid. So far as these curves are concerned, I might refer him to my book on *Surfaces of the Third Order*, Art. 73.

[3] Plücker, *Crelle's Journal*, vol. xxxiv.; Cayley, *Phil. Mag.* July 1861; Chasles, *Comptes Rendus*, vol. xliii.

Kew Electrograph Results for 1880



Illustrating Mr Whipple's Paper on Observations of Atmospheric Electricity at the Kew Observatory during 1880

Observations of Atmospheric Electricity at the Kew Observatory during 1880. *By* G. M. Whipple, *B.Sc.*, *F.R.A.S.*, *F.M.S.*, *Superintendent.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

[Plate VII.]

The results of the observations of Atmospheric Electricity made at the Kew Observatory have been published at various times, but principally in a long paper of eighty-seven pages in the Report of the British Association for the year 1849, by Mr. W. R. Birt, F.R.A.S., and in a paper by Professor Everett, F.R.S., in the 'Philosophical Transactions' for 1868.

The first paper treated of the eye-observations made by the aid of the beautiful apparatus designed by the late Sir Francis Ronalds, whilst the latter was based on the reduction of the photographic continuous records derived from Sir William Thomson's well-known divided ring Electrometer, in connection with a water-dropping collector.

Since the beginning of 1873 a quadrant Electrometer has been in almost constant work. By the kindness of Mr. De La Rue, who allowed the use of his large chloride of silver battery for the purpose, the value in absolute measure of the deflections of this instrument has been determined, and therefore we are now able to give the potential of the Atmospheric Electricity at Kew from time to time in volts instead of in arbitrary values, as has been done in preceding discussions.

Owing to the incessant and frequent changes in the atmospheric tension, the tabulation of the photographic traces with any degree of certainty entails a considerable amount of labour, and although Professor Everett devised a most ingenious method of obtaining the hourly mean values from the curves, yet we found it impossible in the ordinary work of the Observatory to devote the time to the instrument that it necessitated, and hence our seven years' indications have up till recently remained unavailable for discussion.

Lately I succeeded in devising a modification of Professor Everett's method, and constructed a glass scale, by means of which the tabulation of the curves can be effected with the greatest facility and expedition. Accordingly we have now commenced the tabulation and discussion of the accumulated records, and, by the kind permission of the Meteorological Council, I am able to lay a few of the facts derived from the curves for 1880 before the members of the British Association.

Having determined the values of the atmospheric tension for every hour during the year, when measurement of the trace was possible, the diurnal, monthly, and annual variations were computed.

For brevity I only give here the values of the mean monthly, diurnal, and annual ranges, which are as follows. See Tables I. and II.

Having plotted these, the curves were contrasted with those given by Mr. Birt and by Professor Everett, with the view of finding what, if any difference, in the phenomena observed may be attributed to instrumental causes.

As Mr. Birt in his discussion treats separately the positive and negative tensions, we have also omitted the negative readings, which are comparatively few in number, and compared the results with the similar values

TABLE I.—Mean Tension of Atmospheric Electricity at the Kew Observatory in the Year 1880.

Month	Tension expressed in Divisions of Scale. 1 Division equals 10 Volts.																								Means
	Noon 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	
January .	15·0	15·3	13·6	13·7	12·8	15·5	18·9	18·7	20·7	18·8	16·4	14·8	13·3	11·6	11·3	11·0	10·6	10·7	12·0	12·2	12·3	15·6	15·8	14·2	14·3
February .	13·5	11·5	10·8	9·3	11·7	14·2	13·0	12·6	13·5	14·5	13·9	12·2	12·7	13·8	11·8	10·0	10·0	9·7	9·6	10·4	12·0	14·0	14·3	13·0	12·2
March .	10·8	10·9	11·2	10·2	10·9	10·5	11·5	14·0	15·0	16·3	15·5	14·1	13·8	13·0	13·9	15·2	16·0	15·5	15·9	17·2	16·6	15·1	11·7	10·7	13·6
April . .	5·5	5·4	5·4	6·0	6·0	7·5	8·5	9·3	12·1	13·3	14·1	13·3	12·3	11·8	11·6	9·2	8·7	8·9	8·7	9·7	9·6	8·7	6·0	5·6	9·2
May . .	2·2	2·1	2·1	2·1	1·9	3·5	4·3	5·5	6·5	7·5	9·2	7·0	7·3	7·7	6·1	5·7	6·0	6·2	5·9	7·1	6·6	4·5	3·3	3·5	5·2
June . .	3·8	3·3	3·8	4·1	4·3	3·6	4·3	4·5	4·8	6·3	6·8	5·9	6·1	6·0	6·1	5·8	5·7	5·1	5·7	5·5	4·7	4·0	3·2	3·7	4·9
July . .	4·8	5·5	4·7	3·9	4·1	5·2	5·6	6·2	6·9	7·1	7·6	7·0	6·3	5·5	4·8	4·0	4·2	4·8	4·9	5·1	5·3	5·5	3·8	6·0	5·4
August . .	3·9	3·6	3·3	2·7	2·6	2·8	3·4	5·5	5·8	5·5	5·5	4·8	4·2	4·2	3·3	3·2	3·0	2·8	3·3	3·8	3·6	3·0	2·3	3·6	3·7
September .	4·7	5·1	4·7	5·2	4·6	4·8	5·6	5·6	6·2	6·1	5·6	6·0	4·3	3·9	3·7	3·6	3·6	3·9	4·0	4·2	3·7	3·7	3·1	6·6	4·7
October . .	6·6	6·4	6·4	7·3	8·0	8·6	10·4	11·3	12·1	10·9	10·5	9·1	8·2	8·0	8·3	7·9	7·6	7·0	7·3	8·3	7·0	7·8	7·4	7·2	8·3
November .	10·5	11·0	11·1	11·1	11·3	11·7	13·1	14·5	15·5	15·1	14·5	12·6	11·5	10·1	9·0	8·3	8·4	8·0	8·6	9·3	8·6	10·7	9·9	9·4	11·0
December .	13·1	13·6	14·1	12·8	13·0	15·2	14·9	14·7	15·1	14·6	15·4	11·7	9·8	9·5	8·7	7·1	5·6	5·7	5·4	8·0	10·5	12·6	12·9	13·3	11·6
Means . .	7·9	7·8	7·6	7·4	7·6	8·6	9·5	10·2	11·2	11·3	11·3	9·9	9·1	8·8	8·2	7·6	7·4	7·4	7·6	8·4	8·4	8·8	7·8	8·1	8·7

TABLE II.—Mean Tension of *Positive* Atmospheric Electricity at the Kew Observatory in the year 1880.

Month	Tension expressed in Divisions of Scale. 1 Division equals 10 Volts.																								Means
	Noon 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt. 12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	
January .	15·0	15·3	13·6	14·4	14·3	15·5	18·9	20·9	20·7	18·8	16·4	14·8	13·3	12·6	13·0	11·0	10·6	10·7	12·0	12·2	12·3	15·6	15·8	15·1	14·7
February .	15·1	13·6	11·7	10·1	12·4	14·2	13·0	15·3	15·3	17·2	13·9	13·8	13·5	13·8	12·7	10·6	10·5	10·2	10·0	11·1	13·1	16·0	16·6	14·1	13·2
March . .	10·8	10·9	11·2	10·2	10·9	10·5	11·5	14·0	15·0	16·3	16·4	14·1	13·8	13·7	13·9	15·2	16·0	15·5	15·9	17·2	16·6	15·1	11·7	10·7	13·6
April . .	6·3	6·8	6·4	6·5	6·6	8·4	9·0	10·0	12·1	13·9	14·4	13·3	12·8	12·3	11·6	9·2	9·1	9·5	9·1	9·7	9·6	9·5	7·0	7·1	9·6
May . .	3·7	3·5	3·0	2·8	2·7	3·8	4·5	5·9	7·1	8·2	9·2	8·4	7·9	7·7	6·6	5·9	6·0	6·2	5·9	7·1	6·8	5·1	3·7	4·2	5·7
June . .	4·4	4·1	4·4	4·4	4·6	4·1	5·1	5·5	5·6	7·4	7·2	6·2	6·4	6·3	6·1	5·8	5·7	5·7	6·5	5·9	5·5	4·5	4·2	4·3	5·4
July . .	5·4	5·5	4·7	4·1	4·1	5·2	5·6	6·2	6·9	8·2	8·0	7·0	6·3	5·5	5·1	4·7	4·2	4·8	4·9	6·0	5·8	5·9	4·2	6·0	5·6
August . .	4·4	4·3	3·6	3·2	3·3	3·6	3·8	5·5	6·0	5·5	5·5	4·8	4·2	4·2	3·4	3·2	3·0	3·1	3·7	3·8	3·6	3·0	2·3	4·0	4·0
September .	5·5	5·5	5·3	5·2	4·6	4·8	5·6	5·9	6·2	6·8	6·3	6·0	4·9	4·2	3·8	3·6	3·6	3·9	4·0	4·2	3·7	3·9	3·5	7·0	4·9
October . .	7·3	7·9	7·9	7·3	8·3	9·6	11·9	12·4	12·6	12·1	12·0	11·8	9·8	9·1	9·8	9·0	9·3	8·3	8·6	8·3	7·3	8·3	7·4	7·6	9·3
November .	11·5	11·0	11·1	11·1	11·3	11·7	13·9	14·5	15·5	15·1	14·5	12·6	11·5	10·1	9·4	8·8	8·4	8·4	8·6	9·3	8·6	10·7	9·9	11·0	11·2
December .	14·4	14·9	14·1	14·2	14·7	16·0	15·6	15·5	16·7	16·0	16·0	11·7	10·3	10·4	9·5	7·8	5·9	6·4	6·5	9·7	11·7	13·1	12·9	14·0	12·4
Hourly Means	8·7	8·6	8·1	7·8	8·2	8·9	9·9	11·0	11·6	12·1	11·6	10·4	9·6	9·2	8·7	7·9	7·7	7·7	8·0	8·7	8·7	9·2	8·3	8·8	9·1

he obtained. The separation in our case does not produce any marked influence on the final curves, the general features of diurnal and annual changes being virtually identical in both.

The mean diurnal curve for 1880 closely follows Professor Everett's, indicating a minimum tension of about 74 volts at 3 P.M., and rising to a maximum of 113 volts at 9 and 10 P.M., from which there is a steady fall to a second minimum of 74 volts at 4 A.M., afterwards rising to the other maximum of 88 volts at 9 A.M.

In both cases the very rapid fall of tension observed by Birt to take place between 10 P.M. and midnight disappears in favour of a more gentle descent. The difference between the diurnal and nocturnal minimum tensions so conspicuous in the periodical eye-observations also disappears in the continuous records.

TABLE III.—Values of Electrical Tension distributed according to Wind-direction.

1880	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
				Monthly Means				
January	14·7	9·	13·7	9·	10·	14·	15·	9·
February	9·	11·	—	1·	11·5	13·	—	14·
March	—	12·8	14·4	—	—	—	13·	10·
April	7·7	7·3	11·	12·	13·3	8·7	10·6	—
May	5·3	5·4	8·7	—	—	5·2	4·3	4·
June	3·6	4·5	4·3	6·	6·	7·	4·6	—
July	5·	4·5	2·	4·	5·7	5·4	6·	5·
August	4·5	3·	—	—	—	5·	5·5	6·
September	5·	—	2·	5·	3·5	5·	6·	3·5
October	12·	7·6	4·	0·	—	6·3	9·3	10·8
November	15·3	13·7	—	—	10·	10·3	8·8	9·
December	13·0	10·	—	—	28·	8·	11·	25·
				Quarterly Means				
Dec., Jan., Feb.	13·3	10·0	13·7	6·3	13·4	10·9	12·1	19·6
March—May	6·3	8·3	12·9	12·0	13·3	7·2	8·8	6·0
June—August	4·1	3·4	3·7	5·0	5·8	5·7	5·3	5·5
Sept., Oct., Nov.	13·3	8·7	2·5	2·5	4·8	7·7	7·7	9·0
				Semi-annual Means				
March—August	5·0	6·1	10·9	8·5	8·3	6·2	6·4	5·8
Sept.—Feb.	13·3	8·9	9·2	4·8	11·9	9·2	9·9	12·8
				Annual Means				
	9·6	6·9	10·3	6·4	10·3	8·0	8·2	10·9

As regards the curve of annual variation of tension, we find that for 1880 the curve more closely resembled that of 1845–7 than it did that of 1863. The months of maximum mean tension were January, when it was 143 volts, and March 136; and of minimum, August 37 volts, and September 47 volts.

Mr. Birt also found the minimum took place in August, but the maximum in January and February.

Professor Everett gave maxima in November and December, and minima in May and July, with a second minimum in January.

The curves of diurnal range for each month have also been contrasted, and it is found that, as a rule, the curves of the three series closely resemble one another, indicating in all cases a much greater variation in tension during the twenty-four hours in the winter months than in the summer, the relative values of the diurnal range being for 1880, in volts—

January .	101	April .	90	July . .	37	October .	57
February .	52	May .	73	August .	35	November .	75
March .	70	June .	36	September .	35	December .	100

the mean for the year being 66.

TABLE IV.—Values of Electrical Tension corresponding to Wind-Velocities.

1880.	Total horizontal movement of the air in 24 hours in Miles													
	1–50	51–100	101–150	151–200	201–250	251–300	301–350	351–400	401–450	451–500	501–550	551–600	601–650	651–700
Monthly Means														
January . .	19·5	15·	12·	13·	9·	16·	—	—	10·	7·	—	—	—	—
February . .	19·	22·	15·	17·	16·	8·	8·	—	4·5	—	7·5	—	6·	5·
March . .	—	15·5	13·	10·	15·	12·5	11·	19·	13·	16·	—	—	—	—
April . .	—	—	18·	8·	10·	10·	—	7·5	6·5	3·	7·	—	—	—
May . . .	—	—	4·	5·5	6·	6·	3·	5·	4·	6·	—	—	—	—
June . . .	—	17·	6·	5·	6·	3·	4·	4·	—	—	—	—	—	—
July . .	—	5·5	4·	6·	7·	5·	4·	4·	—	—	—	—	—	—
August . .	—	5·	6·5	4·	3·	4·	2·5	3·	—	—	—	—	—	—
September . .	5·	3·4	7·	5·4	5·5	4·	—	—	—	—	—	—	—	—
October . .	7·	8·	12·	5·5	14·	7·	4·	0·	0·	4·5	—	2·	—	—
November . .	—	12·	14·5	17·	11·	12·	10·	10·	8·	13·	—	7·	2·	—
December . .	13·	—	18·	11·	13·	11·	7·	7·	8·	4·5	—	—	—	—
Quarterly Means														
Dec., Jan., Feb. .	17·7	17·2	15·7	12·6	13·8	11·7	7·0	7·7	5·3	7·0	7·5	—	6·0	5·0
March—May .	—	15·5	9·4	7·3	9·0	9·9	7·7	10·3	8·1	7·8	7·0	—	—	—
June—August .	—	6·1	5·2	5·0	4·7	4·0	3·4	5·0	—	—	—	—	—	—
Sept., Oct., Nov.	5·5	7·9	12·4	6·6	10·3	6·7	8·8	5·0	6·0	7·3	—	2·5	2·0	—
Semi-annual Means														
March—August .	—	7·7	7·2	8·1	6·5	6·4	5·9	9·1	8·1	7·7	7·0	—	—	—
Sept.—Feb. .	9·0	10·0	14·3	9·8	11·7	8·4	7·8	6·8	5·5	7·2	7·5	2·5	4·0	5·0
Annual Means														
	9·0	10·7	11·1	8·9	8·7	7·3	6·7	8·4	6·7	7·5	7·3	2·5	4·0	5·0

The variation of Atmospheric Electricity at Kew with some of the other meteorological elements has already been briefly investigated; Professor Everett having indicated the similarity between the curve of diurnal variation of tension with that of the diurnal variation of the barometer, whilst Mr. Birt directed his attention to the relation between electricity and the quantity of aqueous vapour in the air.

The striking resemblance between the curves of diurnal variation of electrical tension and of barometric pressure has also been found to run all through 1880, and the same fact has been noticed at Greenwich by Mr. Ellis, as well as the apparent lagging behind of the barometric curve by from one to two hours.

The fact of frequency of negative tension with rain has long been observed; but it is found that it is almost always accompanied with large and rapid excursions on the side of positive tension, and therefore the average hourly value of the tension during such periods is seldom low.

One year's data can scarcely be considered to give perfectly decisive results; but it is believed that the following conclusions may be drawn from the observations now under discussion.

In the first case, it is found that generally the relations differ in summer and in winter; their variations are therefore given as well as their means.

TABLE V.—Values of Electrical Tension corresponding to varying amounts of Cloud.

1880	Tenths of sky covered.				
	0–2	3–4	5–6	7–8	9–10
			Monthly Means		
January . . .	22·3	13·	15·7	17·	11·5
February . . .	17·	16·	14·5	13·	9·8
March . . .	14·7	13·5	14·6	12·3	8·5
April	—	5·	10·4	10·3	8·
May	6·	6·2	5·	5·5	5·
June	—	5·	6·	5·	5·
July	—	5·	6·	5·5	4·7
August . . .	5·	—	3·7	4·7	3·
September . . .	2·7	3·3	5·7	5·6	4·3
October . . .	17·	8·2	13·	14·3	5·3
November . . .	16·	15·3	13·3	10·6	6·3
December . . .	22·	10·	18·	11·	8·
			Quarterly Means		
Dec., Jan., Feb. . .	20·7	13·0	16·7	12·9	9·9
March, April, May .	13·8	9·0	9·6	9·0	6·6
June, July, August .	5·0	5·0	5·1	5·2	4·2
Sept., Oct., Nov. . .	11·7	8·8	9·7	9·2	5·3
			Semi-annual Means		
March—August . .	12·3	7·9	7·7	6·4	5·3
September—February .	15·6	10·3	12·7	10·9	7·7
			Annual Means		
	14·2	9·2	9·7	8·4	6·6

1st. *Wind*—direction. It is found at Kew that for the year the maximum tension (109 volts) occurs with north-westerly winds, and the minimum (64) with south-easterly winds; but for the summer months the tension is greatest (109 volts) with an east wind, and lowest (50) with a north wind; whilst in winter the conditions are almost reversed, and northerly and north-westerly winds have the strongest tensions—133 and 128 volts respectively, and south-easterly the weakest, with 48. See Table III.

These results may be influenced by the intensity of the wind, as it is found that, contrary to what one would imagine, light winds have a higher potential than strong breezes, the average tension being in the latter case but about one-third of that in the former.

This, however, is not very well-marked in summer, when there does not seem to be a very defined relation between the two phenomena; it is almost entirely due to the winter observations. See Table IV.

2nd. *Cloud.* Both summer and winter results agree in giving a direct ratio between the electrical tension of the air and the cloudiness of the sky; the average tension under an almost cloudless sky being more than double what it is under a completely overcast one, the observed values being for the former 142 volts, and for the latter 66. See Table V.

Table VI.—Values of Mean Daily Tension corresponding to different Values of the Mean Daily Relative Humidity of the Air.

	Relative Humidity, complete saturation being 100.							
1880	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–99
				Monthly Means				
January	—	—	—	15	14	15	14	—
February	—	—	—	—	14	9	11	18
March	—	16	15	16	12	10	—	—
April	7	7	6	9	11	11	18	—
May	5	5	6	4	3	—	—	—
June	—	6	5	5	6	4	4	—
July	—	—	6	5	5	6	—	—
August	—	—	5	4	3	2	—	—
September	—	3	4	4	6	5	4	—
October	—	—	24	11	11	6	4	3
November	—	—	15	10	13	10	7	—
December	—	—	—	11	10	10	15	6
				Quarterly Means				
Dec., Jan., Feb.	—	—	—	13	12	1	14	15
March—May	5	7	8	10	11	10	20	2
June—August	—	6	5	5	5	4	4	—
Sept., Oct., Nov.	—	3	10	9	9	8	4	3
				Semi-annual Means				
March—August	5·2	7·3	6·4	7·1	6·5	6·8	11·8	2 0
Sept.—Feb.	—	3·0	10·3	9·8	10·2	9·8	11·0	11·4
				Annual Means				
	5·2	6·5	6·9	8·1	8·2	9·1	11·0	10·5

Relative Humidity.—Table VI. The different degrees of tension corresponding to varying amounts of relative humidity cannot well be determined. On the whole, tension rises as the moisture of the air increases, being about 50 volts when the air is but half-charged with moisture, and over 100 volts when at the point of complete saturation; the variation, however, is not regular, either in summer or winter, becoming much more rapid as the point of saturation is approached; this is probably due principally to the high tensions always observed during the prevalence of fogs.

The Thomson electrometer at Kew, from which these results have been deduced, having been subjected to necessary re-adjustment from time to time since its scale-value was originally determined, the tensions given above may possibly need correction at some future date, but as no radical change affecting the accuracy of the instrument has been made, it is assumed the values here given are not far from the truth.

Owing to the unsuitability of the instrument for the registration of phenomena of very brief duration it is not possible to give any values for the tensions observed during periods of great electrical disturbance, such as thunder or hail storms; it may, however, be remarked that on such occasions the deflections of the needle far exceed the limits of registration of the electrograph, which are from about − 150 to + 600 volts.

Excursions of the dot of light through a considerably larger range than the above may be watched taking place with every flash of lightning during a storm, but the rate of movement across the paper is far too rapid to permit of photographic registry.

Magnetic disturbances and auroræ are not found to produce any marked changes in the indications of the instrument.

On the Arrestation of Infusorial Life by Solar Light. *By* Professor JOHN TYNDALL, *F.R.S.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

THREE years ago I brought with me to the Alps a number of flasks charged with animal and vegetable infusions. The flasks had been boiled from three to five minutes in London, and hermetically sealed during ebullition.

Two years ago I had sent to me to Switzerland a batch of similar flasks containing other infusions. On my arrival here this year, one hundred and twenty of these flasks lay upon shelves in my little library. Though eminently putrescible, the animal and vegetable juices had remained as sweet and clear as when they were prepared in London.

Still an expert, taking up one of the flasks containing an infusion of beef or mutton, would infallibly pronounce it to be charged with organisms. He would find it more or less turbid throughout, with massive flocculi moving heavily in the liquid. Exposure of the flask for a minute or two to lukewarm water would cause both turbidity and flocculi to disappear, and render the infusion as clear as the purest distilled water. The turbidity and flocculi are simply due to the coagulation of the liquid to a jelly. This fact is some guarantee for the strength of the infusions.

I took advantage of the clear weather this year to investigate the action of solar light on the development of life in these infusions, being prompted thereto by the interesting observations brought before the Royal Society by Dr. Downes and Mr. Blunt in 1877.[1] The sealed ends of the flasks being broken off, they were infected, in part by the water of an adjacent brook and in part by an infusion well charged with organisms. Hung up in rows upon a board, half the flasks of each row were securely shaded from the sun, the other half being exposed to the light. In some cases, moreover, flasks were placed in a darkened room, within the house, while their companions were exposed in the sunshine outside.

The clear result of these experiments, of which a considerable number were made, is that by some constituent or constituents of the solar radia-

[1] *Proc. Roy. Soc.*, December 6.

tion, an influence is exercised inimical to the development of the lowest infusoria. Twenty-four hours usually sufficed to cause the shaded flasks to pass from clearness to turbidity, while thrice this time left the exposed ones without sensible damage to their transparency.

This result is not due to mere differences of temperature between the infusions. On many occasions the temperature of the exposed flasks was far more favourable to the development of life than that of the shaded ones. The energy which, in the cases here referred to, prevented putrefaction was energy in the *radiant* form.

In no case have I found the flasks *sterilized* by insolation; for on removing the exposed ones from the open air to a warm kitchen they infalliby changed from clearness to turbidity. Four and twenty hours were in most cases sufficient to produce this change.

Life is therefore prevented from developing itself in the infusions, as long as they are exposed to the solar light; and the paralysis, thus produced, enables them to pass through the night-time without alteration. It is, however, a *suspension*, not a *destruction* of the germinal power, for, as before stated, when placed in a warm room life was invariably developed.

Had I had the requisite materials I should have determined, by means of coloured media, or otherwise, the particular constituents of the solar radiation which are concerned in this result. The rays, moreover, which thus interfere with life, must be absorbed by the liquid, or by its germinal matter. It would, therefore, be interesting to ascertain whether, after transmission through a layer of any infusion, the radiation still possessed the power of arresting the development of life in the same infusion. It would also be interesting to examine how far insolation may be employed in the preservation of meat from putrefaction.

Note.—I would not be understood to say that it is impossible to sterilize an infusion by insolation, but merely to indicate that I have thus far noticed no case of the kind.

On the Effects of Oceanic Currents upon Climates.
By the Rev. Samuel Haughton, *M.D., F.R.S.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

The Gulf Stream and its counter-current, the Labrador current, produce important effects upon climate, which I propose to investigate in some detail, as much misapprehension exists as to what they do and do not do; and I propose further to consider what the effect of similar currents and counter-currents would be, if admitted to the Arctic Ocean from the Pacific through a widened and deepened Behring Strait, and if admitted to the Arctic Ocean, from the Indian Ocean and Arabian Sea (by lowering Mesopotamia), through the Great Caspian depression in the west of Asia.[1]

[1] Mr. Alfred Russel Wallace has ingeniously proposed these two additional Gulf Streams as causes of climatal changes in recent Geological times in the Arctic Zone, but he does not seem to be aware of the effects of the counter-currents they would necessarily produce.

Prop. I.—*It is required to calculate the effects of the Gulf Stream upon the climates of the North Atlantic and Arctic Regions.*

The following table shows the mean annual temperature, for all longitudes, of the several latitudes in the northern and southern hemispheres:

Lat. N.	Annual Temperature	Lat. S.	Annual Temperature
0°	80°·1 F.	0°	80°·1 F
10°	81°·0	10°	78°·7
20°	77°·6	20°	74°·4
30°	67°·6	30°	66°·7
40°	56°·5	40°	57°·9
50°	43°·4	50°	47°·8
60°	29°·3	60°	35°·3
70°	14°·4		
80°	4°·5		

From this it appears that the northern hemisphere is warmer than the southern from lat. 0° to lat. 30°, and that it is colder than the southern from lat. 40° to lat. 60°.[1] The higher temperature of the southern hemisphere in the temperate latitudes is explained by the existence of three gulf-streams in that hemisphere, while there is only one in the North Atlantic, and a partial one through Behring Strait, in the northern hemisphere.

If we make use of Ferrel's Tables [2] of temperature for each parallel of latitude affected by the Gulf Stream in the North Atlantic, we find the following results:—

Mean Annual Temperatures.

Lat. N.	Range of Longitude influenced by Gulf Stream			Mean temperature of air above Gulf Stream	Mean temperature of all other Longitudes
40°	0°	to	50° W.	61°·60 F.	55°·68 F.
50°	10° E.	„	30° W.	52°·00	42°·01
60°	20° E.	„	20° W.	44°·60	26°·83
70°	20° E.	„	10° W.	30°·00	11°·07
80°	70° E.	„	10° W.	11°·22	2°·26

The last column shows the temperature to which the climates affected by the Gulf Stream would fall, if the Gulf Stream were to cease, and the differences are shown in the following table:—

Local and General Fall of Temperature occasioned by the supposed cessation of the Gulf Stream.

Mean Annual Temperatures.

Lat. N.	Local fall at Gulf Stream Longitudes	General fall at all other Longitudes
40°	5°·92 F.	0°·82 F.
50°	9°·99	1°·39
60°	17°·77	2°·47
70°	18°·93	3°·33
80°	8°·96	2°·24

[1] In point of fact, the latitude at which the mean annual temperature, at all longitudes, is the freezing-point of water is 58° 51′ in the northern hemisphere, and 62° 41′ in the southern hemisphere; or, in other words, the latitude of mean temperature of 32° F. lies nearer the Pole in the southern hemisphere than in the northern, by 3° 50′ or 230 geographical miles. This makes a very sensible difference between the two hemispheres.

[2] *United States Coast Survey Meteorological Researches for the use of the Coast Pilot.* Part I. By William Ferrel, M.A., 1877.

If, instead of tabulating the mean annual temperatures, we tabulate the mean July and January temperatures, we obtain the following results :—

Mean July Temperatures.

Lat. N.	Temperature at Gulf Stream Longitudes	Temperature at all other Longitudes	Diff.
40°	70°·00 F.	73°·40 F.	− 3°·40 F.
50°	63°·80	65°·77	− 1°·97
60°	57°·40	56°·94	+ 0°·46
70°	44°·75	44°·24	+ 0°·51
80°	32°·78	34°·54	− 1°·76
Sum	268°·73	274°·89	

From this table we see that the Gulf Stream adds nothing to the July temperatures of the localities affected by it, but rather, on the whole, has the effect of slightly diminishing the summer heat. This fact will be of extreme importance when we come to discuss the question of the Tertiary Climate of the Arctic Regions.

Mean January Temperatures.

Lat. N.	Temperature at Gulf Stream Longitudes	Temperature at all other Longitudes	Diff.
30°[1]	63°·43 F.	53°·21 F.	+ 10°·22 F.
40°	52°·00	37°·93	+ 14°·07
50°	40°·00	18°·28	+ 21°·72
60°	33°·60	− 3°·44	+ 37°·04
70°	20°·75	− 20°·03	+ 40°·78
80°	− 10°·44	− 29°·85	+ 19°·41
Sum	+ 199°·34	+ 56°·10	

From this table it is evident that the action of the Gulf Stream upon the climates of high latitudes consists simply in raising the winter heat, while the summer heat remains unaffected and the mean annual temperature is raised by about half the amount of rise in the January temperature.

The general climatal effect of the Gulf Stream is therefore to make the annual range of temperature less;[2] (the climate more insular), but it has no effect whatever upon summer heat, or upon the fruiting of plants and trees, that require a given July temperature for reproduction.

These effects, as the table shows, reach a maximum somewhere about 70° N. lat.

The two following tables show the effect that would be produced upon the mean July and January temperatures, at all longitudes by a supposed withdrawal of the Gulf Stream.

Mean July Temperatures at all Longitudes.

Lat. N.	With Gulf Stream	Without Gulf Stream	Diff.
40°	73°·0 F.	73°·4 F.	− 0°·4 F.
50°	65°·5	65°·8	− 0°·3
60°	57°·0	56°·9	+ 0°·1
70°	44°·3	44°·2	+ 0°·1
80°	34°·1	34°·5	− 0°·4
		Mean	− 0°·18 F

This table proves that the effect of the Gulf Stream upon temperature

[1] Longitudes (10° W. to 70° W.) are the Gulf Stream longitudes for 30° N. lat.

[2] This effect also diminishes the range of secular variation of temperature, depending on the eccentricity and perihelion longitude of the earth's orbit.

in July at all latitudes is nil; and that the ripening of seeds and fruits depends on sunheat and latitude only.

Mean January Temperatures at all Longitudes.

Lat. N.	With Gulf Stream	Without Gulf Stream	Diff.
40°	40·0° F.	37·9° F.	+ 2·1° F.
50°	21·3°	18·3°	+ 3·0°
60°	1·7°	− 3·4°	+ 5·1°
70°	− 15·5°	− 20·0°	+ 4·5°
80°	− 25·0°	− 29·8°	+ 4·8°

Prop. II.—*It is required to calculate the effects of the* Kuro-Siwo (*Japan current*) *upon climates in the North Pacific, and its effect upon high latitudes, if it were admitted to the Arctic Ocean through Behring Strait, widened and deepened.*

Following the same method that I have used for the Gulf Stream, I find the effects of the Kuro-Siwo in the North Pacific to be as follow:—

North Pacific. Mean July Temperatures.

Lat. N.	Longitudes influenced by Kuro-Siwo	Mean Temperature of Kuro-Siwo Longitudes	All other Longitudes	Diff.
40°	130° W. to 180° W.	63·33° F.	74·93° F.	− 11·60° F.
50°	140° W. „ 180° W.	58·00°	66·71°	− 8·71°
60°	140° W. „ 170° E.	52·33°	57·93°	− 5·60°
70°[1]	120° W. „ 150° W.	48·50°	43·84°	+ 4·66°

This table shows that the summer effect of the Kuro-Siwo upon the North Pacific is even less than the summer effect of the Gulf Stream upon the North Atlantic. The reason of this is, that although the Kuro-Siwo is a much larger current than the Gulf Stream, it is required to heat a much larger area, for the North Pacific is much larger than the North Atlantic.

The effects produced in winter by the Kuro-Siwo are shown in the following table:—

North Pacific. Mean January Temperatures.

Lat. N.	Longitudes influenced by Kuro-Siwo	Mean Temperature of Kuro-Siwo Longitudes	All other Longitudes	Diff.
30°	120° W. to 160° E.	57·89° F.	54·30° F.	+ 3·59° F.
40°	110° W. „ 170° E.	48·00°	37·33°	+ 10·67°
50°	110° W. „ 160° E.	34·80°	16·11°	+ 18·69°
60°	130° W. „ 170° E.	10·43°	−0·59°	+ 11·02°
70°	Kuro-Siwo produces no effect.			

[1] This represents the effect of the portion of the Kuro-Siwo which enters Behring Strait in summer, and extends eastward as far as Banks' Land, but is unable to enter in winter.

If we bring together the January effects of the Gulf Stream in the North Atlantic, and of the Kuro-Siwo in the North Pacific, we shall see the difference between them most clearly.

Effects of Gulf Stream and Kuro-Siwo upon January Temperatures.

Lat. N.	Gulf Stream Excess	Kuro-Siwo Excess	Diff.
30°	+ 10·22° F.	+ 3·59° F.	+ 6·63° F.
40°	+ 14·07°	+ 10·67°	+ 3·40°
50°	+ 21·72°	+ 18·69°	+ 3·03°
60°	+ 37·04°	+ 11·02°	+ 26·02°
70°	+ 40·78°	nil.	+ 40·78°
80°	+ 19·41°	nil.	+ 19·41°

The following considerations help to explain the differences produced in the North Atlantic and North Pacific by their respective systems of ocean-circulation :—

1. The ocean-currents at the equator and within the tropics are caused by the trade winds.

2. The trade winds are caused by the equatorial evaporation and subsequent precipitation of vapour as rain, and the force of the trade winds is proportional to the rate of evaporation.

Combining these propositions, we find that the volume of the equatorial current will be proportional to the equatorial breadth of the ocean and to the rate of evaporation, jointly.

The following tables show the mean annual temperatures of the tropical latitudes of the North Atlantic and Pacific Oceans.

North Atlantic Ocean.

Latitude	Longitudes	Mean Annual Temperature
0° N.	10° E. to 50° W.	79·86° F.
10° N.	20° W. „ 60° W.	80·40°
20° N.	20° W. „ 100° W.	77·89°
	Mean	79·38° F.

North Pacific Ocean.

Latitude	Longitudes	Mean Annual Temperature
0° N.	80° W. to 120° E.	79·08° F.
10° N.	90° W. „ 110° E.	78·77°
20° N.	110° W. „ 110° E.	74·64°
	Mean	77·48° F.

The ratio of the mean breadths of the two oceans in the given latitudes is—

$$\frac{\text{Pacific}}{\text{Atlantic}} = \frac{1600}{625} = 2{\cdot}56$$

The ratio of the vapour-tensions of the mean annual temperatures of the two oceans, in the given latitudes, is—

$$\frac{\text{Pacific}}{\text{Atlantic}} = \frac{\text{Vapour Tension of } 77^\circ{\cdot}48 \text{ F.}}{\text{Vapour Tension of } 79^\circ{\cdot}38 \text{ F.}} = \frac{0{\cdot}947 \text{ in.}}{1{\cdot}001 \text{ in.}}$$

Hence, the approximate ratio of the volumes of the Pacific and Atlantic equatorial currents, which produce the Kuro-Siwo and Gulf Stream, is

$$\frac{1600}{625} \times \frac{947}{1001} = 2{\cdot}422.$$

Or, in other words, the forces producing the Kuro-Siwo are nearly two and a half times greater than the forces producing the Gulf Stream.

To find, from the foregoing ratio of the volumes of the two ocean-streams, that of their heat-producing effect, we must multiply by the excess of temperature above 32° F., or by

$$\frac{77°{\cdot}48\ F. - 32°{\cdot}0\ F.}{79°{\cdot}38\ F. - 32°{\cdot}0\ F.} = \frac{45{\cdot}48}{47{\cdot}38}$$

from which we find the ratio of the effect (in melting ice) of the Kuro-Siwo to the Gulf Stream.

Relative heating effect of

$$\frac{\text{Kuro-Siwo}}{\text{Gulf Stream}} = 2{\cdot}422 \times \frac{4548}{4738} = 2{\cdot}325$$

In order to find the actual relative effect of the Pacific and Atlantic ocean-currents in affecting climate at any locality we must further take account of the relative areas over which these effects are spread. In the North Pacific, the January temperatures are raised from the 30th parallel of latitude to the 65th parallel; and in the North Atlantic, from the 40th parallel to the 80th parallel. I have calculated the relative areas of these surfaces, and find it to be as 44,014 to 24,511.

Hence the absolute heating effect of the Kuro-Siwo, as compared with the Gulf Stream, will be

$$\frac{\text{Pacific}}{\text{Atlantic}} = 2{\cdot}325 \times \frac{24511}{44014} = 1{\cdot}295$$

From these calculations it follows that although the volume of the Kuro-Siwo is 2·42 times greater than that of the Gulf Stream, its heating effect is only 1·29 times greater.

We are now in a position to calculate numerically the effect upon climate that would be produced by widening and deepening Behring Strait. I shall suppose it widened and deepened from the Kamtschatka mountain range on the west to the mouth of the Mackenzie river on the east, by the submersion of the Tchukchi land, and of Aliaska and Alaska.

Parallel of 60° N. January Temperature.

In the North Atlantic, the effect of the Gulf Stream is shown by its raising the temperature of January, from long. 30° W. to long. 10° E., to a mean of + 32°·8 F., whereas the mean temperature of this parallel at all longitudes is only + 1°·7. The July temperatures remain unaffected.

If we now suppose the Kuro-Siwo admitted through the widened Behring Strait to produce a similar effect in the proportion of 129 to 100, we obtain the following results:—

The present mean January temperatures at Behring Strait are as follows at 60° N.:—

Long. 170° E.	+ 12° F.
„ 180° E.	− 26°
„ 170° W.	− 24°
„ 160° W.	− 22°
„ 150° W.	− 23°
„ 140° W.	− 24°
„ 130° W.	− 26°
Mean	− 19°·00

As stated above, the effect of the Gulf Stream, in the North Atlantic, is to raise the temperature of January from $+ 1°·7$ F. to $32°·8$ F. through 40° of longitude affected by it. The effect of the Kuro-siwo admitted through Behring Strait, may therefore be measured by a corresponding rise of temperature, through

$$40 \times 1·29 = 51°·6 \text{ of longitude.}$$

This would produce a mean January temperature, at all longitudes, equal to

$$\frac{32·8 \times 51·6 + 1·7 \times 308·4}{360} = 6°·16 \text{ F.}$$

This raising of the January temperature, at Behring Strait, from $- 19°·0$ F. to $32°·8$ F. would, of course, produce in the longitudes affected by it an important effect in saving from destruction plants and trees which would perish at $- 19°·0$ F. in winter, but would give no benefit whatever to plants requiring a given July temperature to ripen their seeds.

Its effect, at all longitudes, is to raise the January temperature through $4°·46$ F. and the mean annual temperature through $2°·23$ F.

Parallel of 70° *N.* *January Temperature.*

The January temperatures, in the N. Atlantic at 70° lat., are raised by the Gulf Stream, from long. 10° W. to long. 20° E., to a mean of $+ 20°·75$ F., instead of $- 15°·5$ F. at all longitudes, the July temperatures remaining unaffected.

The corresponding effects at Behring Strait (widened and deepened) would be thus found, assuming as before the proportion of 5 to 4 for the relative thermal effects of the Kuro-Siwo and Gulf Stream:

Present mean January temperatures at Behring Strait longitude at 70° N. lat.

Long. 160° W.	− 22°·0 F.
,, 150° W.	− 23°·0
,, 140° W.	− 24°·0
,, 130° W.	− 26°·0
,, 120° W.	− 28°·0
Mean . .	− 24°·6 F.

Calculating, as before, the effect of the Kuro-Siwo (admitted through Behring Strait) upon all longitudes, I find that it would raise the January temperature through

$$30 \times 1·29 = 38°·7 \text{ of longitude,}$$

from $- 24°·6$ F., which is the present temperature of the longitudes affected, to the temperature of $+ 20°·75$ F., and that the consequent January temperature at all longitudes would be :—

$$\frac{20·75 \times 38·7 - 15·5 \times 321·3}{360} = - 11°·53 \text{ F.}$$

The January rise of temperature at all longitudes is therefore $3°·97$ F., and the rise of mean annual temperature is $1°·99$ F.

This alteration would confer little benefit upon plant-life at that high latitude.

Parallel of 80° N. Lat. January Temperature.

The January temperatures, in the N. Atlantic at lat. 80°, are raised by the Gulf Stream, from long. 0° to long. 60° E., from − 25°·0 F. to − 10°·4 F.; the July temperatures remaining unaffected. The corresponding effects of the Kuro-Siwo at Behring Strait (widened and deepened), would be as follows, on the same supposition as before, as to the relative thermal effects of the ocean-streams.

Present mean January temperatures at Behring Strait at 80° lat.

Long.	170° E.	− 33°·0 F.
„	180° E.	− 33°·0
„	170° W.	− 32°·0
„	160° W.	− 32°·0
„	150° W.	− 33°·0
„	140° W.	− 34°·0
„	130° W.	− 35°·0
„	120° W.	− 37°·0
„	110° W.	− 39°·0
	Mean . .	− 34°·22

Calculating, as before, the effect of the Kuro-Siwo (admitted through Behring Strait), I find that it would raise the mean January temperature from − 34°·22 F. to − 10°·44 F. through

$$60 \times 1{\cdot}29 = 77°{\cdot}4 \text{ of longitude}$$

affected by it.

This gives, for the consequent January temperature, at all longitudes:

$$\frac{-10{\cdot}44 \times 77{\cdot}4 - 25{\cdot}0 \times 282{\cdot}6}{360} = -21°{\cdot}87 \text{ F.}$$

The January rise of temperature, at all longitudes, is therefore 3°·13 F., and the mean annual rise in temperature is 1°·57 F.

Placing all these results together, we obtain the following effects upon the January temperatures of the Arctic Regions produced by the admission of the Kuro-Siwo through Behring Strait.

Lat.	Local Effect			General Effect		
	Temperature before	Temperature after	Diff.	Temperature before	Temperature after	Diff.
60°	− 19°·0 F.	+ 32°·80 F.	51°·80 F.	+ 1°·7 F.	+ 6°·16 F.	4°·46 F.
70°	− 24°·6	+ 20°·75	45°·35	− 15°·5	− 11°·53	3°·97
80°	− 34°·2	− 10°·44	23°·76	− 25°·0	− 21°·87	3°·13

As the July temperatures remain unaffected all through, zoologists and botanists can readily estimate the trifling effects of this change of climate upon animal and plant life.

We have hitherto considered the *direct* effects of tepid ocean-currents, like the Gulf Stream and Kuro-Siwo, if admitted into the Arctic Ocean, and have found that they produce no effect whatever upon the summer temperature of the higher latitudes, although they unquestionably benefit the winter temperatures of those latitudes.

We must now examine the *indirect* effects of the admission of these tepid ocean-currents, which are perhaps of more serious importance to the welfare of plants and animals.

When an ocean-current moving from south to north obtains admission to the Arctic Ocean, it produces necessarily, on hydrodynamical principles, an equal and opposite counter-current moving from north to south. The tepid water-current is forced by the rotation of the earth to shift its direction continually to the right, and thus it happens that the Gulf Stream is pressed upon the western shores of Europe and Spitzbergen, and benefits those localities in winter. On the other hand the cold counter-current returning through Baffin's Bay and along the east coast of Greenland, is also forced by the earth's rotation to keep to its right, and so is pressed upon the coast of Labrador and the east coast of North America as far south as Cape Cod. This return or counter current, known as the Labrador Current, and others, exercises an influence upon climate the opposite of that of the Gulf Stream, and of such a kind as to render it very doubtful whether the Gulf Stream is a real benefit to the climate of the whole globe or not.

While the Gulf Stream *raises* the January temperature of all places visited by it, the Labrador or counter-current *lowers* the July temperature of all places affected by it. This is readily shown by the following figures:—

July Temperatures, North Atlantic.

Lat. N.	Longitudes affected by Labrador Current	All other Longitudes	Diff.[1]
40°	70°·0 F.	73°·0 F.	3°·0 F.
50°	60°·0	65°·5	5°·5
60°	47°·0	57°·0	10°·0
70°	38°·0	44°·3	6°·3

Similar, though lesser, effects are to be found on the east coast of Asia, caused by the counter cold current issuing from Behring Strait, and pressing to the right along that coast.

Remembering that the Gulf Stream is helpless to increase the July temperatures, upon which the reproduction of plants is chiefly dependent, we may confidently assert that the serious lowering of July temperature caused indirectly, by means of its counter-current, through the agency of the Gulf Stream, has a more important influence upon the geographical distribution of plants than its direct influence in mitigating the severity of the winter months.

If we imagine the Kuro-Siwo admitted into the Arctic Ocean, by a broad deep channel to the east of Kamtschatka, we must bear in mind the fact already proved, that although its thermal effect is only one and a quarter times that of the Gulf Stream, its actual volume is two and a half times as much; and by the laws of hydrodynamics, the counter cold current moving south-west produced by it, will be two and a half times greater than the Labrador current. Supposing it to be a little less cold, and discounting the counter-current already issuing from Behring Strait, we cannot estimate the damaging effect of the counter Kuro-Siwo current at less than double that of the Atlantic Labrador current. What effect will this produce upon the climate of eastern Asia?

When we remember that the cold counter-currents of the Gulf Stream are able to cover Greenland with perpetual ice, and bring the iceberg-limit down to 60° N., it is not unreasonable to suppose that the North Pacific counter-currents caused by the admission of the Kuro-Siwo through

[1] These differences would be still greater if we were to leave out of account the longitudes affected by the higher temperature of the Gulf Stream.

Behring Strait, having at least double the volume of the Atlantic counter-currents, would bring the iceberg-limit in eastern Asia as far south as Pekin [1] (40° lat.), and cover the valley of the Amoor and the northern Japanese islands with a coating of glacial ice.[2]

The destruction of vegetation caused by the Kuro-Siwo counter-currents would be far more than equivalent to the small benefits obtained in January temperatures from its admission to the Arctic regions.

Prop. III.—*It is required to calculate the effects upon climate of an ocean-current admitted to the Arctic Ocean from the Indian Ocean, across the Caspian and Aral Sea depression, to the east of the Ural Mountain-chain and Nova Zembla.*

This ocean-current has been suggested by Mr. Alfred R. Wallace as a probable cause of recent changes in climate, and is highly probable on geological grounds.

The mean width of the Indian Ocean, in tropical latitudes, as compared with that of the Atlantic Ocean, is as 520 to 625. The mean annual temperatures of the air in the Indian Ocean are—

North Indian Ocean.

Latitude	Longitudes	Mean Annual Temperature
0° N.	40° E. to 100° E.	80°·6 F.
10° N.	50° E. „ 100° E.	81°·5
20° N.	60° E. „ 90° E.	79°·5
	Mean	80°·53

The vapour-tension corresponding to this temperature is 1·035 in.

Hence, following the same method as before, we find the ratio of volumes of

$$\frac{\text{N. Indian Ocean current}}{\text{N. Atlantic Ocean current}} = \frac{520}{625} \times \frac{1001}{1035} = 0{\cdot}805.$$

The relative thermal (ice-melting) effects of the two currents will be found by multiplying by the excess of temperatures above the freezing-point, or

$$\frac{80^\circ{\cdot}53 \text{ F.} - 32^\circ{\cdot}0 \text{ F.}}{79^\circ{\cdot}38 \text{ F.} - 32^\circ{\cdot}0 \text{ F.}} = \frac{48{\cdot}53}{47{\cdot}38}$$

This gives, finally, for the ratio of the thermal effects :—

$$\frac{\text{N. Indian Ocean}}{\text{N. Atlantic Ocean}} = 0{\cdot}805 \times \frac{48{\cdot}53}{47{\cdot}38} = 0{\cdot}824.$$

Hence we may conclude that the supposed North Indian Ocean current, both in volume and thermal effect, would amount to about four-fifths of the present Gulf Stream, whereas the North Pacific Ocean current would have five-fourths of the thermal effect of the Gulf Stream and two and a

[1] If the Labrador counter-current were twice its present volume, it is highly probable (if North America were at the same time depressed a few hundred feet) that the limit of the edge of ice in spring would reach the latitude of New York, and that all the glacial phenomena of that continent would be reproduced.

[2] The absence of all traces of glaciation or of ice-transport of boulders in the Altai Mountain ranges, and indeed throughout Eastern Siberia, renders it highly probable that Behring Strait was not widened and deepened in recent Geological times, although it has often been dry land.

half times its volume, which latter determines the amount and volume of the counter-current of cold water.

If we calculate from Ferrel's Tables, as before the effect of the new North Indian Ocean current, reckoned as four-fifths of the Gulf Stream, we find as follows:—

Latitude 60°.—It will raise the January temperature, from 70° E. long. to 102° E. long., from − 10°·0 F. to + 32°·8 F.; which is equivalent to a rise at all longitudes from + 6°·16 F. to + 8°·53 F.

Latitude 70°.—It will raise the January temperature, from 80° E. long. to 104° E. long., from − 18°·33 F. to + 20°·75 F.; which is equivalent to a rise at all longitudes from − 11°·53 F. to − 9°·35 F.

Latitude 80°.—It will raise the January temperature, from 90° E. long. to 130° E. long., from − 27°·4 F. to − 10°·44 F., which is equivalent to a rise at all longitudes from − 21°·87 F. to − 20°·3 F.

If we bring together, into one point of view, all the preceding results, we find the following changes of winter climate produced in the Arctic regions by the successive introduction of the Gulf Stream, the Kuro-Siwo (North Pacific Stream), and the North Indian Ocean Stream.

(*A*) *Temperatures before Admission of the Gulf Stream.*

Lat.	July	Mean	January	Range
60°	57°·0 F.	26°·80 F.	− 3°·4 F.	60°·4 F.
70°	44°·3	12°·15	− 20°·0	64°·3
80°	34°·1	2°·15	− 29°·8	63°·9

(*B*) *Present Temperatures.*

Lat.	July	Mean	January	Range
60°	57°·0 F.	29°·3 F.	− 1°·7 F.	58°·7 F.
70°	44°·3	14°·4	− 15°·5	59°·8
80°	34°·1	4°·5	− 25°·0	59°·1

(*C*) *Temperatures after opening Behring Strait.*

Lat.	July	Mean	January	Range
60°	57°·0 F.	31°·58 F.	− 6°·16 F.	50°·84 F.
70°	44°·3	16°·38	− 11°·53	55°·83
80°	34°·1	6°·11	− 21°·87	55°·97

(*D*) *Temperatures after admitting the North Indian Ocean Stream, to the east of the Ural Chain, through the Caspian Sea depression.*

Lat.	July	Mean	January	Range
60°	57°·0 F.	32°·76 F.	− 8°·53 F.	48°·47 F.
70°	44°·3	17°·47	− 9°·35	53°·65
80°	34°·1	6°·9	− 20°·3	54°·4

After all the tepid ocean-streams are admitted, it is plain that the Arctic regions would still remain very uncomfortable quarters for either plants or animals. Further, if the admission of the North Indian Ocean current through the Caspian were accompanied by a depression of Northern Europe through some hundred feet, its counter-current would act under most favourable circumstances for lowering the July temperature of Europe, and might even produce all the known glacial phenomena of Scandinavia, the British Islands, Switzerland, and the Pyrenees.

Corollary.—The magnitude of a glacier, *cæteris paribus*, depends upon that of the snow-field in which it takes its origin; and any depression of the line of perpetual snow will increase the magnitude of the snow-field and glaciers.

The height of the line of perpetual snow depends upon two factors only: (1) the temperature of the summer months (July); (2) the supply of aqueous vapour to form the snow.

This fact is well illustrated by the following table, which is copied from a paper by Mr. Joseph J. Murphy, read in 1875, before the Belfast Natural History and Philosophical Society, and is constructed on the principle (tolerably near the truth) that the temperature of the hottest month in the year decreases in ascending at the rate of 1° F. for every 300 feet.

	Temperature of hottest month at sea-level	Height of 32° F. in hottest month	Height of snow-line
Pyrenees	74·5	12750	9300
Caucasus	77	13500	10300
Mount Blanc	72·5	12150	9000
Bernese Alps	72·5	12150	8800
Scandinavian Fjelde 61°43′ N.	59	8100	5500
Mageroe, Norway, extreme north	45·5	4050	2160
Himalaya, about 31° N., *north side*	83·75	15525	16620
Himalaya, about 31° N., *south side*	83·75	15525	12980
Andes, near Quito	79·25	14175	15795
Do. 18° N.	81·5	14850	14772
Do. near Valparaiso	68	10800	12780
Do. 37°40′ S.	63·5	9450	7960
Straits of Magellan	45·5	4050	3390

On this table, Mr. Murphy remarks, as is stated in the foot note.[1]

Professor Forbes[2] has expressed the opinion, founded on his study of the Norway glaciers, that a diminution of 4° F. in the temperature of the summer months would place one-fourth of the surface of Norway within the snow-line and pour glaciers into the head of every fiord in Western Norway. From a personal study of the Norwegian ice-fields, I am inclined to confirm this statement.

At the latitude of 60° N., the July temperatures of Greenland and Norway, are—

Norway	60° F.	Diff. = 13° F.
Greenland	47°	

[1] It is evident by this table that the snow-line rises above the line of 32° for the hottest month of the year where the snow-fall is small, and sinks below it where the snow-fall is great. In the Caucasus, the Alps, and the Pyrenees, the snow-line is about three-fourths of the height of the line of 32° for the hottest month of the year; in the Fjelde of Norway, about two-thirds; in the Peruvian and Chilian Andes above, but in Patagonia and Tierra del Fuego below; above, on the north side of the Himalaya, but below on the south side. These contrasts are all to be explained by the difference in the amount of snowfall, which is greater on the south than on the north side of the Himalaya, greater in Patagonia and Tierra del Fuego than in Chilé and Peru, and probably greater, at least in winter, in Norway than in Central, Southern, or Eastern Europe.

The dependence of the height of the snow-line on summer temperature and on amount of snowfall, to the exclusion of winter temperature, may be best shown, perhaps, by two extreme cases. The mean temperature of the Altai mountains is below freezing; yet, in consequence of the comparatively warm summer, and the small snowfall, the height of the snow-line is about 6,000 feet. In the Straits of Magellan, on the contrary, though the mean temperature is several degrees above freezing, the height of the snow-line (see table) is little more than half as much.

[2] *Norway and its Glaciers*, p. 243.

This represents a fall of summer temperature more than three times as great as would be required to glaciate Norway.

At the latitude of Dublin we have

Dublin	68° F.	Diff. = 20° F.
Nain (Labrador) . .	48°	

This fall of temperature in July would probably be sufficient to glaciate the whole of the British Islands down to the sea-level.

On Magnetic Disturbances and Earth-currents. *By* Professor WILLIAM GRYLLS ADAMS, *F.R.S.*

[PLATES VIII.–XIII.]

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

IN considering the changes or disturbances produced in the three magnetic elements, viz., the declination, the horizontal force, and the vertical force, we must distinguish between the regular changes, which depend on the apparent motions of the sun or the moon, and those more sudden and sometimes violent changes which are especially termed magnetic disturbances.

Among the regular changes are daily and yearly changes, which depend on the time of the day and the season of the year, showing that the change of position and the apparent motion of the sun with respect to the place of observation produce regular magnetic changes. These regular daily changes are accompanied by and have very generally been supposed to be due to electric currents or electric waves traversing the earth's crust; and a discussion by Dr. Lloyd of the observations made by Mr. Barlow, in 1847, of currents on telegraph wires, showed a very close relationship between the two-hourly changes of the declination needle and the changes of intensity and direction of earth-currents on telegraph lines.

Both Dr. Lamont and Dr. Lloyd conclude, from their comparisons of earth-currents and magnetic changes, that the changes of the declination needles cannot be due to the direct action of the electric current traversing the earth's crust, but that these currents or waves, extending to a considerable depth, alter by induction the magnetism of the earth itself, and this change of magnetism causes the observed changes in the declination needle. Thus the magnetic changes are the indirect effects of —not the earth-current in its immediate neighbourhood but of—a change in the magnetism of the earth itself, which may be due to an electric wave extending over a considerable area of the earth's surface.

The point towards which the total earth-current is directed follows the sun, and seems to lag two or three hours behind, but not the same distance behind at different places.

These earth-currents have been ascribed to different causes; thus Dr. Lamont regards them as the results of electric force emanating from the sun; De Saussure regards them as developed by evaporation, the vapour being positively charged, and the water being negative; Dr. Lloyd regards them as effects of solar heat; whilst M. de la Rive ascribes them to chemical action going on in the interior of the solid crust of the earth, the electricity being transpórted into the atmosphere by evaporation.

Mr. Ellis, of the Greenwich Observatory, has shown the intimate relation between solar action and the regular diurnal magnetic changes of declination and horizontal force at Greenwich Observatory during thirty-five years, from 1841 to 1876, by a comparison of the observations of those elements. The results of his observations are recorded in a valuable paper published in the 'Philosophical Transactions of the Royal Society' (vol. 171, part ii. 1880), and they show what a close relationship exists between solar activity and terrestrial magnetic changes. There are not only daily and yearly periods of the variations of different magnetic elements, but there also seems to be in the horizontal force a period of 25 or 26 days, which is the time of rotation of the sun on his axis. Such a period would be a very strong argument in favour of regarding the sun as a magnetic body, in which, as in the earth, the axis of rotation does not coincide with the magnetic axis.

Other recent investigations have shown that these regular magnetic changes depend not only on the sun, but that they are also in part due to the action of the moon; and these portions depend upon the length of the lunar day, and on the position of the moon with regard to the earth. Just as there are regular earth-currents, whose direction depends upon the sun, which we may call the solar earth-currents, so there are lunar earth-currents which go through their changes under the action of the moon; and it has been shown that the effects are produced, not immediately under the moon, but that there is a lagging behind in the case of the lunar earth-currents, just as in the case of the solar earth-currents. In the case of the lunar earth-currents we cannot attribute the production of the electricity either to heat or to thermo-electric currents from one part to another of the earth's crust, and we must therefore look for some other source. May we not find it in the fact that the moon causes tides in the solid crust of the earth, just as she causes tides in the oceans? The earth's crust is made up of elastic materials and materials capable of yielding and altering their form to a considerable amount with the change in the direction of the pull of the moon upon them.

This crust also contains magnetic substances in abundance, which alter their form under the moon's attraction, and so, from the changes of relative position of masses of magnetic matter, changes are produced in the magnetism of the earth, which must give rise to induced currents of electricity or earth-currents. Let us imagine a conductor of electricity outside the earth, stretching from the north pole to the equator, and fixed in space, with the earth, a magnetic body, revolving beneath it from W. to E., then it follows, from Faraday's laws of induced currents, that the revolution of the earth on its axis would cause a current in the fixed conductor in a direction from the pole to the equator.

If the conductor moved over the surface of the earth from W. to E., and the earth did not revolve, or revolved at a slower rate, then the current in the conductor would be from the equator to the pole. The current depends upon the relative motion of the earth and the wire. If, then, we have an insulated wire running north and south, the tides in the earth's crust, of which I have spoken, will be equivalent to a lagging behind of magnetic matter, and so we may expect in that wire a current of electricity whose general direction would be from the equator to the pole. The position of the wire with reference to the magnetic pole of the earth would modify the direction of these earth-currents, and it is quite conceivable that the position of England with regard to the magnetic pole might cause these regular earth-currents to be greatest in the S.W. and N.E. direction. The lagging of the lunar earth-currents behind the position of the moon would also be accounted for by the lagging of the tides behind the moon.

If this is a true cause for some portion at least of the lunar earth-currents, then the same reasoning, applied to the sun, may in a smaller degree apply to the case of the regular solar diurnal earth-currents, and may help to account for the lagging behind of the effects due to the sun, so that the fact that the greatest solar effect happens about 2.30 p.m. may not be entirely due to the fact that that is the hottest part of the day, but may also in part depend upon the tides.

We have now to consider those more sudden changes of the suspended magnets which are distinguished by the name magnetic disturbances. In 1874, Dr. Lloyd said of them: 'The duration and the magnitude of these oscillations are as yet outside the domain of law, and probably depend upon so many operating causes that, like the gusts and lulls of the wind in an atmospheric storm, they will long baffle all attempts to refer them to their actuating forces, or even to reduce them to order.'

Certain facts relating to these disturbances were made out from the series of observations started by Gauss in 1834, and made every five minutes at the same time at a variety of places, at first in Europe, and afterwards in various parts of the world.

The disturbing power was found to increase in northern latitudes; also it was made out that the appearance of a disturbance in several places occurred at the same time, but there were great differences in the results at different places.

The force seemed to originate in a certain point in the interior of the earth, and the direction of the disturbing force seemed to be constant, yet sometimes there were great differences in the deviations at places not far apart, and from the result of his observations Weber was led to believe that there was a centre of disturbances, which was somewhere in the neighbourhood of St. Petersburg.

However sudden and unconnected single disturbances may seem to be, they still follow certain laws in their occurrence. Sabine found that they had daily and yearly variations from their mean values, and that they have an 11-year period, which agrees with the 11-year period of the appearance of spots upon the sun.

Disturbances are more frequent in summer than in winter, and this applies to each hemisphere, and it has been confirmed by various observers that they are also subject to the influence of the moon.

Lamont says of these disturbances, their cause is a force which is subject to certain laws, but which does not act constantly; the mean direction and frequency have yet to be discovered. Observations have shown that the magnetic disturbances and electric currents on the earth are so nearly related to one another, that people naturally look upon the electric currents, either in the crust of the earth or in the atmosphere outside it, as the cause of the magnetic disturbances. These currents in the earth have usually been attributed to changes of temperature, because they also are found to be in some way governed by the sun.

The improved methods of recording observations by photography give the opportunity of discovering the laws of the occurrence of magnetic disturbances, and for some years past photographic records have been taken of the magnetic elements, but the curves have been laid aside, and very little use has as yet been made of them.

At the meeting of the British Association last year at Swansea, I laid before the Mathematical and Physical Section an account[1] of a comparison of the Declination Curves taken by precisely similar instruments at six European magnetic observatories, viz., Kew, Stonyhurst, Coimbra, Lisbon, Vienna, and St. Petersburg. Since that time I have had the opportunity, through the kindness of the Kew Committee, of studying the horizontal force curves from these stations, the vertical force curves from some of them as well as the declination and horizontal force curves from Melbourne, and from Zi-ka-Wei in China, for the same period (March 1879). I have also compared the curves from these stations, and from Toronto, for the violent magnetic storm which took place in August, 1880. I have now to bring before you some further points which come out of these comparisons.

It must be remembered that at stations near the poles the horizontal force is smaller in proportion to the total force than it is at stations near to the equator, so that the same disturbance will produce less effect on the horizontal force or on the declination needle, in latitudes near the equator.

Also the needles at different stations are by no means in the same state of sensibility, and even at the same station they change with time, so that they are not always equally sensitive, and when they lose their magnetism they have to be re-magnetised.

Let us take first the disturbances on March 15–16, 1879. (See Plate VIII.) We see that soon after 10 a.m. G.M.T., on March 15, 1879, there is a disturbance wave, showing first a diminution and then an increase in the horizontal force at St. Petersburg, Vienna, Kew, and Lisbon. At Melbourne, in Australia, there is a similar disturbance at the same time, both in the declination and in the horizontal force.

Again, between 2 and 3 p.m., and between 4 and 5, there are very small disturbances, showing themselves at the same absolute time in the horizontal force and declination curves. About 5.20 p.m. there is a well-marked increase in the horizontal force and eastward deflection of the declination needles.

About 9.30 p.m. G.M.T., a storm begins, which lasts for about an hour. It is felt in the northern and in the southern hemispheres, near to and on both sides of the equator. At all European stations the horizontal force is increased during the first part of the storm, and then diminished.

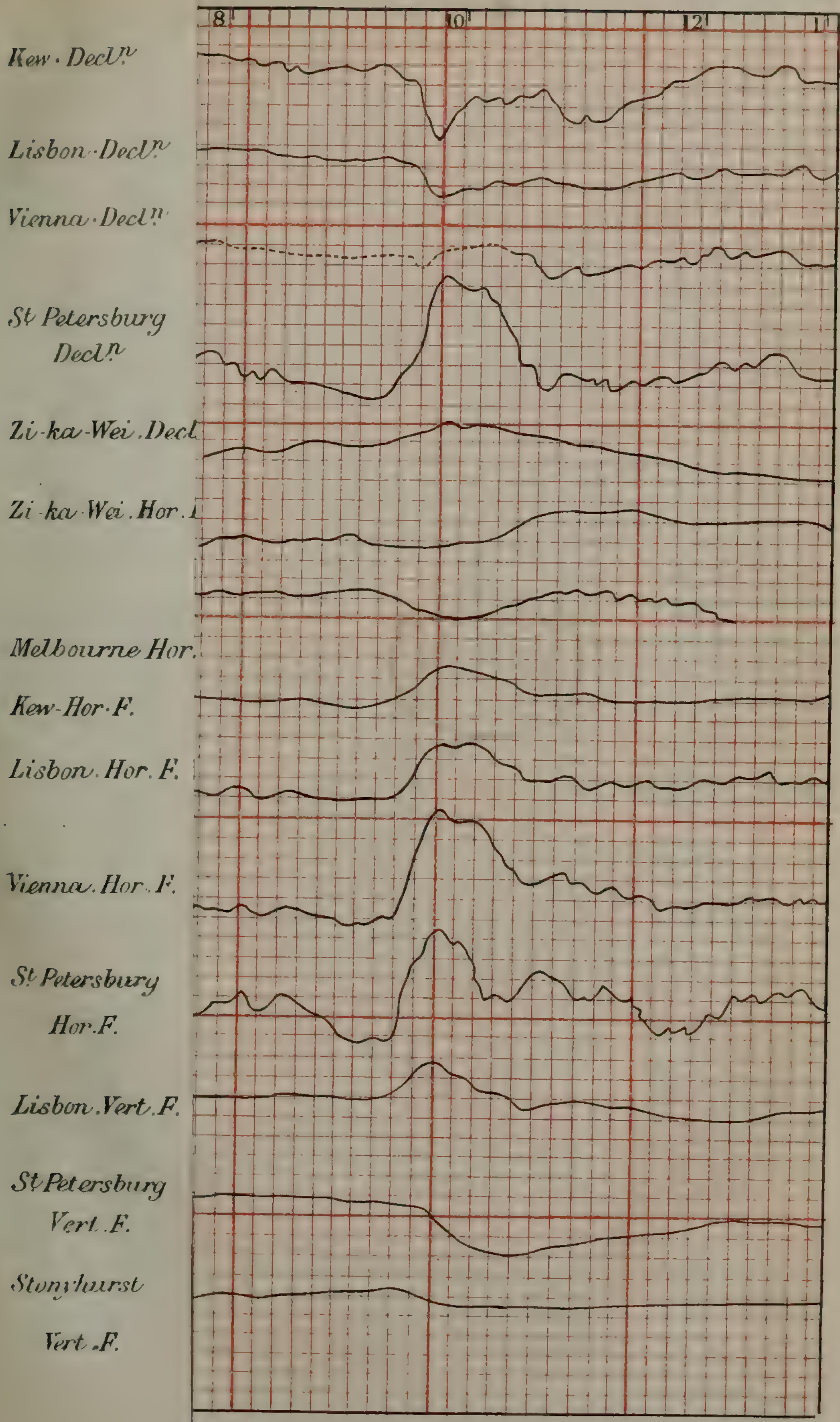
At Lisbon the vertical force is first increased and then diminished, and at St. Petersburg and Stonyhurst there is a diminution in the vertical force at the same time as at Lisbon. If we regard the declination needles we find that at St. Petersburg, Zi-ka-Wei and Melbourne, and at Bombay the declination westward is first increased and then diminished, whereas at Kew and Lisbon the motions are in the opposite direction.

The declination at Vienna seems to be intermediate between Kew and St. Petersburg, but the curve is incomplete. At Bombay and the Mauritius, near to, but on opposite sides of, the equator, the declination needles are deflected opposite ways. The deflections are small, because the needles are not sufficiently sensitive. The local time at these places was from 1 to 2 o'clock at night.

[1] See *British Association Report* for 1880.

LEMENTS.

Plate VIII.

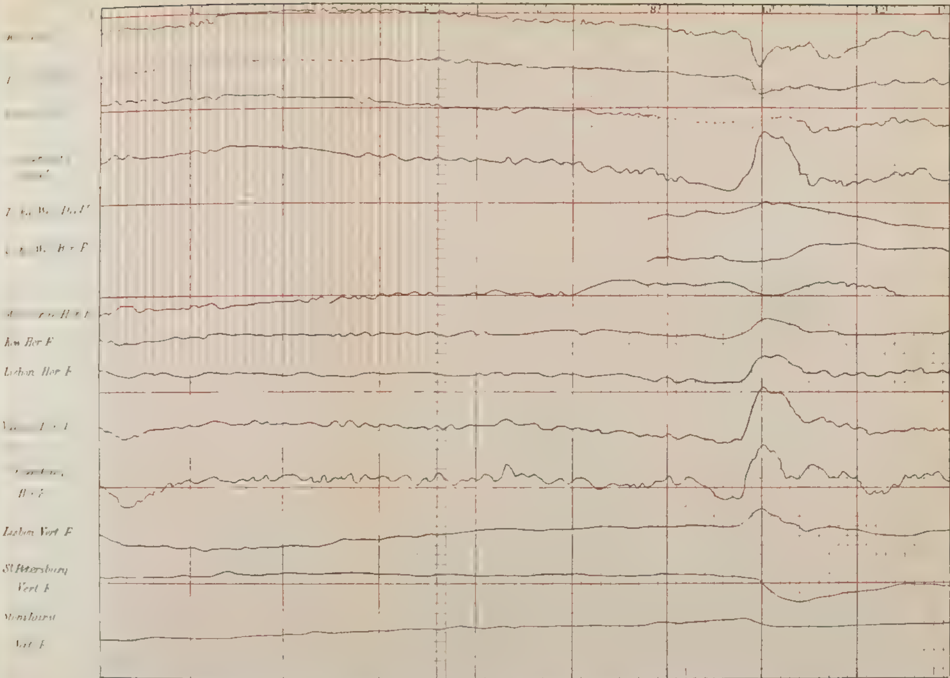


sturbances.

COMPARISON OF MAGNETIC ELEMENTS.

March 15th. 1879.

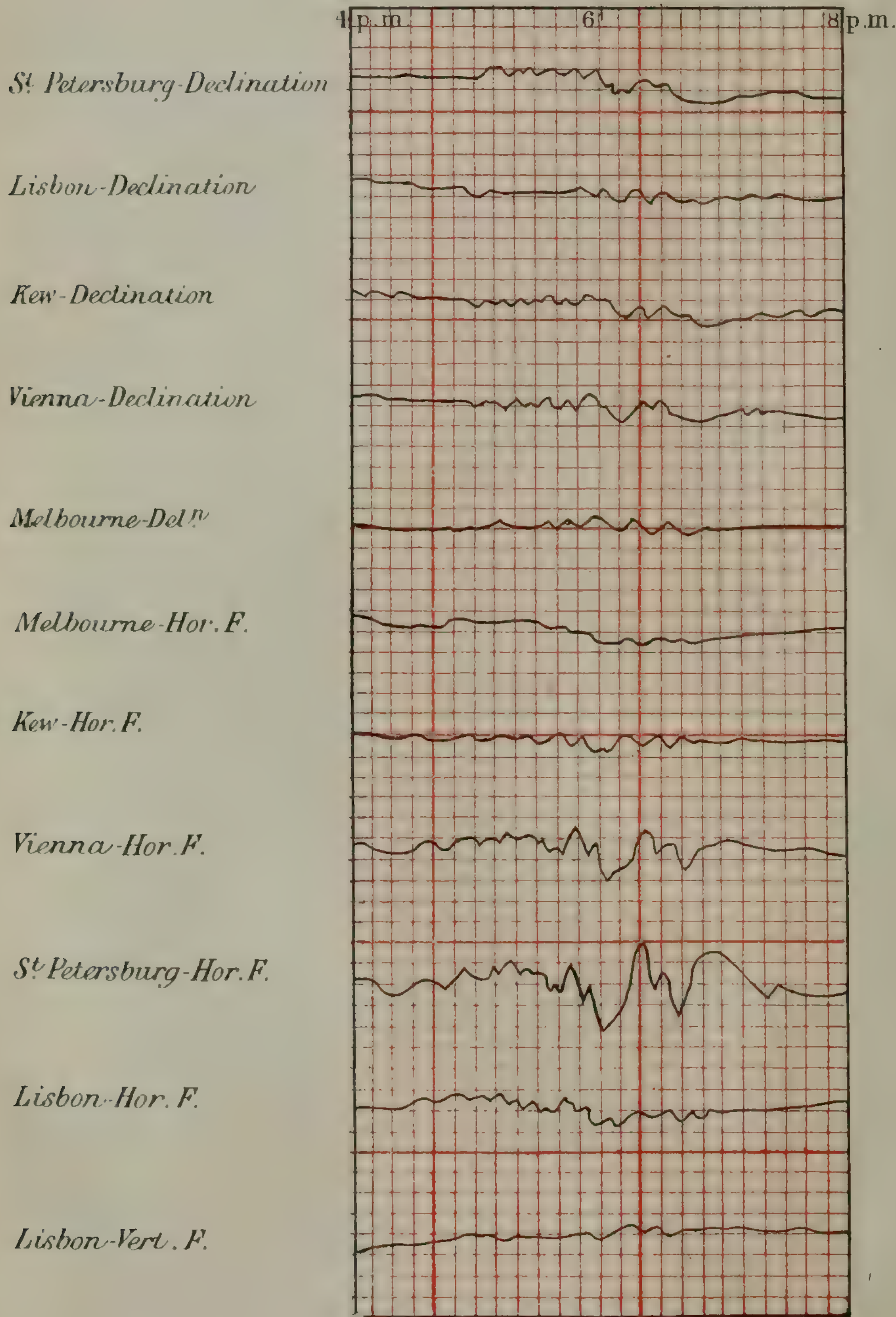
Plate VIII.



Illustrating Professor W. Grylls Adams's Paper on Magnetic Disturbances

COMPARISON OF MAGNETIC ELEMENTS.

March 26th. 1879. Plate IX.



Illustrating Professor W. Grylls Adams's Paper on Magnetic Disturbances.

Now in what way can we account for such magnetic disturbances? If we assume that by magnetic induction from some cause or other the earth's magnetism is altered, then the position of the magnet which would produce the disturbance must be such that its pole, which attracts the marked end of our needle, must lie at the beginning of the disturbance to the E. of Kew and Lisbon, to the N. of Vienna, and to the N.W. of St. Petersburg; the Lisbon vertical force curve also shows it to be below the surface of the earth. Hence an inductive action equivalent to a change of position of the north magnetic pole, towards the geog. pole, would account for these changes. The strengthening and weakening of a magnet, with its N. pole to the N., on the meridian of Vienna, might possibly account for the magnetic changes observed between 9.30 and 10.30 at night, Greenwich time, on March 15, 1879.

If we attempt to explain this disturbance by currents of electricity or discharges of statical electricity in the air above the needles, then we must imagine that at first there is a strong current from the S.W., over St. Petersburg, from the W., over Vienna, and from the N.W., over Kew and Lisbon; the vertical force needle at Lisbon showing that the current from the N.W. lies somewhat to the east of Lisbon. That at the Mauritius this current is from the north, and at Bombay from the south.

Hence we must imagine that a current of electricity passes down from the N.W. to the S.E., going on towards the E. over Vienna, and towards the N.E. over St. Petersburg. This must be kept up very much along the same line throughout the first part of the disturbance, and then the current or currents must be altered in strength in the same manner at all stations.

We will next consider what would hardly be called a magnetic storm, but a few very small deviations of the magnetic needle lasting from about 5.30 to 7.30 p.m. on March 26, 1879. (See Plate IX.) Only the comparison of the originals will give the closeness of the similarity of the curves, and the declination curves of Vienna and Kew are absolutely coincident.

When the declination needle is deflected to the west, the horizontal force-needle is deflected with its marked end towards the south, so that in this disturbance the two needles are drawn towards the S.W. at the same time with greater or less power, and twelve similar curves are clearly traced out in the Vienna and Kew curves during the two hours. These disturbances are all so small that, but for the comparison of photographs, they would probably be lost sight of, yet we see that the same deflections occur at the same instant at Kew and at Vienna, at St. Petersburg and at Melbourne. From the remarkable similarity in these disturbances, and their occurrence at the same time, we should expect that the cause of disturbance is so far removed from the places of observation, that the difference of their distances from it need not be considered. This might not unreasonably be urged as an argument in support of a theory that such disturbances are due directly to the action of the sun regarded as a magnetic body. The numerical comparisons of observations made every five minutes on certain days previously fixed upon, would probably never have shown the way in which these minute changes of the magnetic power of the earth at widely distant places are related to one another.

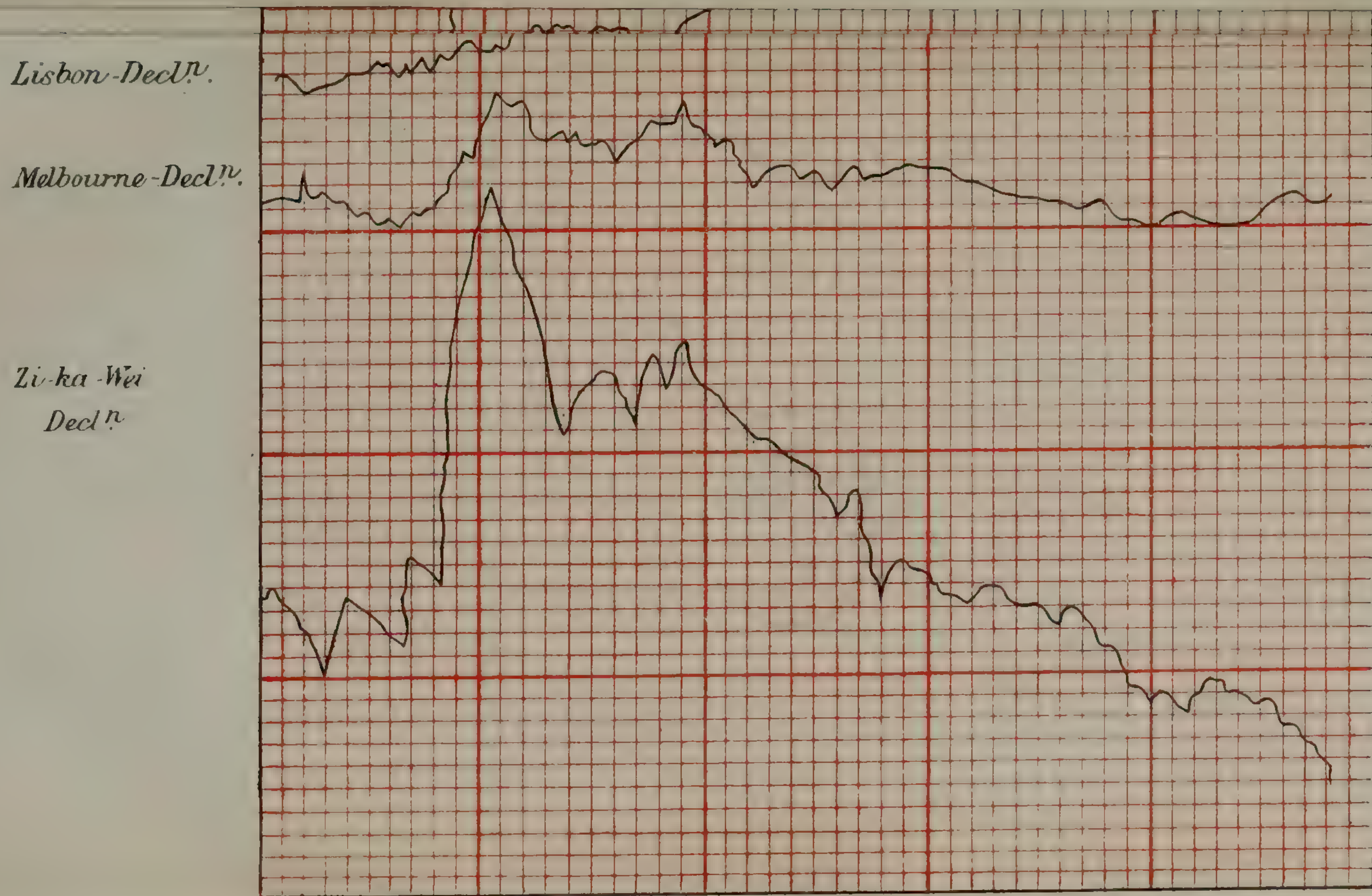
In one or two cases Señor Capello and Professor Balfour Stewart had compared the Lisbon and Kew curves for a particular disturbance, but the photographic magnetic records have never before been collected from other stations, and there has been no opportunity of comparing them. From the precise similarity of the forms of the curves in many cases, we may say that the *rate of change* of magnetic disturbances at widely distant stations is the same. There is nothing fitful or flashing in such disturbances as these of March 26. We might imagine a current in the crust of the earth, or a current or transfer of electricity in the air near to, *i.e.* within twenty or thirty miles of, each of these observatories, but to imagine the same current and the same variations of the current at so many different stations all changing in the same way at the same instant is difficult, unless it can be shown in what way all these changes are connected with the cause of such a regular electric discharge. It seems easier to imagine that such changes as these are due to a change produced by induction in the magnetism of the earth itself by some distant body.

Sometimes disturbances occur where at the same instant there are similar deflections of the declination needles at stations wide apart, and suddenly at one of the stations the needle no longer continues to move with the others, but begins to go, and continues for a considerable period to go, in the opposite direction to the others, turning when they turn, and tracing out a similar curve, but turned always in the opposite direction. Such cases occurred frequently during March 1879, and especially on March 23, about 1.30 and about 7 p.m. Kew time, and on March 29 about 9 p.m.

During the month of August 1880, a very good opportunity occurred for studying a grand magnetic storm, which was accompanied by brilliant displays of Aurora and by earth-currents. This storm began on August 11, and lasted until the 14th, and may be divided into three distinct storms —one lasting from 10.20 a.m. (G.M.T.) on the 11th to 1 a.m. on the 12th; a second from 11.30 a.m. on the 12th to 7.20 a.m. on the 13th; and the third from 11.50 a.m. on the 13th to 7 a.m. on the 14th. Smaller disturbances fill up the interval between the second and third storms.

Four plates have been prepared from very careful tracings from the photographic records at the several observatories. In the cases of Toronto and Zi-ka-Wei the time-scales are not the same as at Kew, and the curves have been taken from carefully drawn curves which have been plotted on the Kew scale. The plates show the principal portions of the three storms. The beginning of the first storm (August 11) is marked at all stations by a sudden considerable increase in the horizontal force. (Plate X.) At Kew the beginning of the storm is not actually recorded, because a new sheet was being put on the cylinder at 10.20 a.m., when the storm was beginning. The Kew deflections are smaller than the others, because the horizontal force needle at Kew was less sensitive than the others, the scale-values being ·00127 mm. mg. for 1 mm. at Kew, as compared with ·00029 mm. mg. for 1 mm. at St. Petersburg. The storm begins at the same instant in Europe, Asia, and America, in high northern and southern latitudes, and also near the equator at Bombay, and everywhere precisely in the same way. It may also be traced at the Mauritius, and there are very distinct similarities of form between the Mauritius and Lisbon curves. The practical value of the curves at the Mauritius and at some other stations is greatly diminished, because the needles do not appear to be sufficiently sensitive to show the character of the magnetic changes.

During the early part of the storm, on August 11, after the first de-

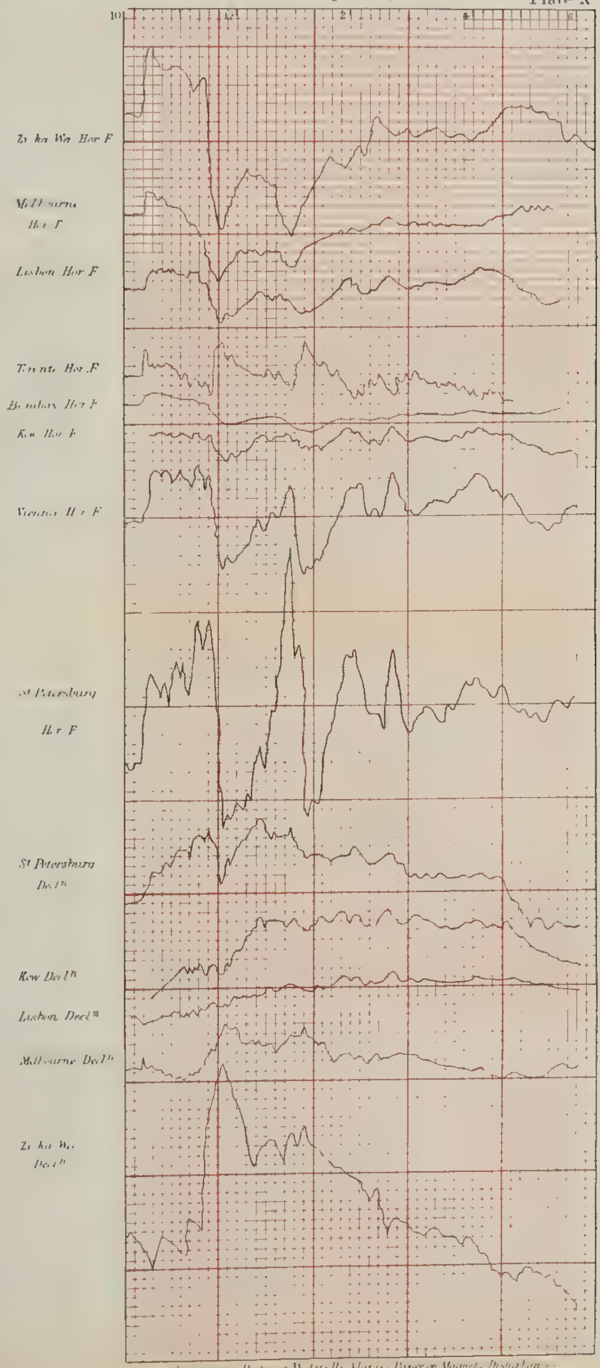


Illustrating Professor W. Grylls Adams's Paper on Magnetic Disturbances

COMPARISON OF MAGNETIC ELEMENTS

10 am to 6 pm. Aug 11th 1880.

Plate X



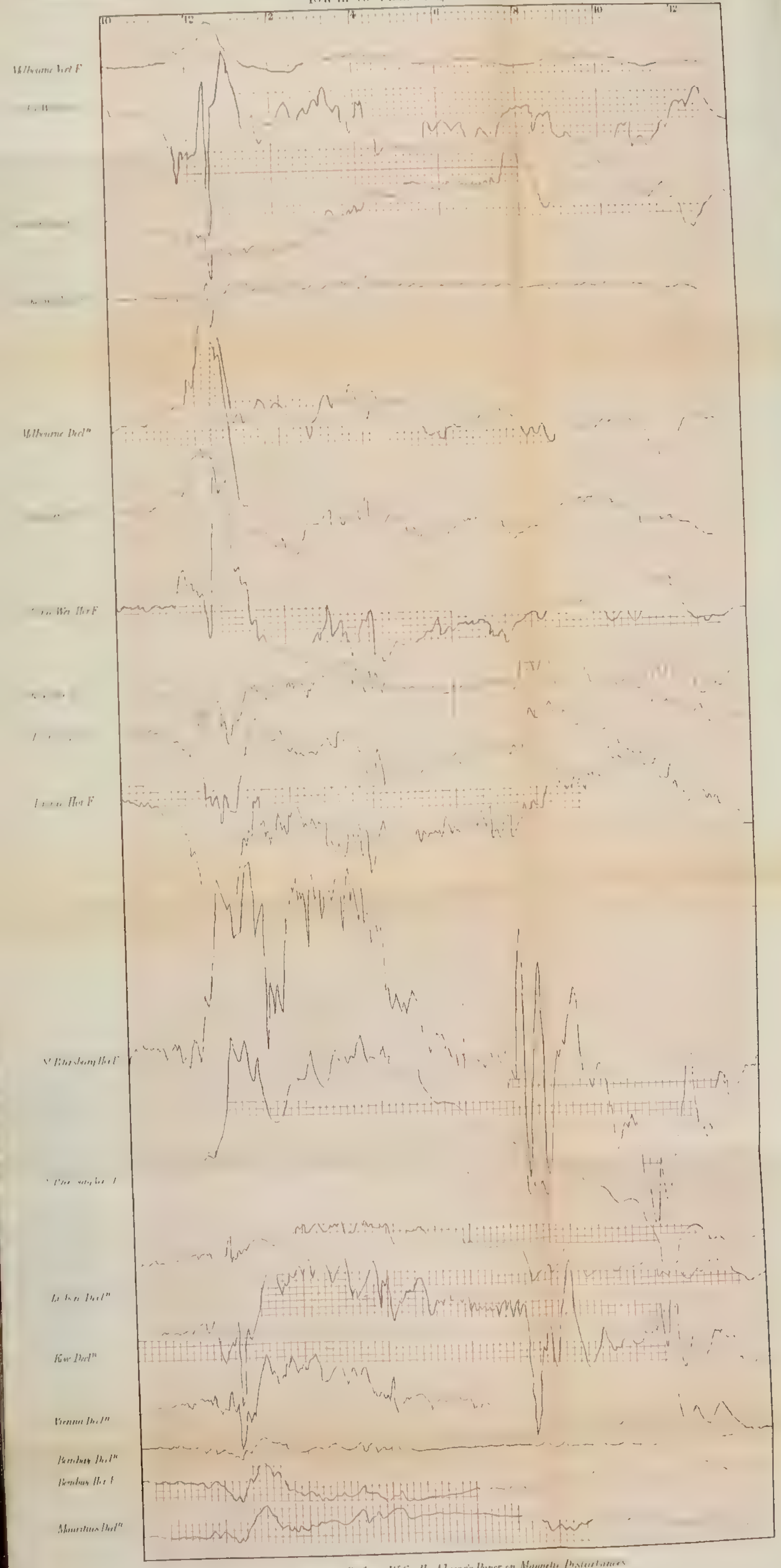
Illustrating Professor W. Grylls Adams's Paper on Magnetic Disturbances.

COMPARISON OF MAGNETIC ELEMENTS.

Illustrating Professor W. Grylls Adams's Paper on Magnetic Disturbances.

COMPARISON OF MAGNETIC ELEMENTS.

10 a.m. to 1 a.m. Aug. 12th, 1880



Illustrating Professor W. Grylls Adams's Paper on Magnetic Disturbances flection, the general direction of the Toronto deflections is opposed to those at the other stations; but from 4 p.m. to 8 p.m. (G.M.T.), *i.e.* from about 10.40 a.m. to 2.40 p.m. Toronto time, the deflections are alike, and in the same direction at Toronto and at European stations. (See Plate XI.) Again, about 11 p.m., there is a very violent phase of the storm, in which the deflections are alike and in the same direction at Toronto, Zi-ka-Wei, and at the European stations.

There is considerable similarity in the form of the Toronto horizontal force curve and the Melbourne declination curve for the beginning of the storm. There is also a remarkably close agreement between the horizontal force curves at Kew and at Vienna during the storm, the differences in the amount of the deflections being due to the fact that the needles are not equally sensitive. The horizontal force curves at Kew and Bombay also agree very closely during the first four hours of the storm, after which the Bombay needle shows very little action.

The second storm, beginning about 11.30 a.m. (G.M.T.) on the 12th, and lasting until the next morning, was the most remarkable of the three. Plate XII. gives the changes in the magnetic elements from 10 a.m. on the 12th to 1 a.m. on the 13th. At about 11.40 a.m. the disturbances begin to become violent, and from 12 to 1 they are so great that in some cases the paper is not wide enough to receive the record, and in others the paper is either not sensitive enough to record the impressions or is so blackened that it is impossible to trace the form of the record upon it. The horizontal force trace at Toronto and the declination trace at Kew go off the paper. At Melbourne and at Vienna the trace fails.

At the time of greatest disturbance, 12.25 p.m., it is very remarkable that at Lisbon and at Zi-ka-Wei near Shanghai, in China, two places nearly in the same latitude but about nine hours apart in time, the vertical force is increased in precisely the same way and to about the same amount at the same instant. There is also a striking similarity between the Melbourne and the Zi-ka-Wei horizontal force curves and between the Zi-ka-Wei and Kew declination curves.

At Zi-ka-Wei the sudden change in the horizontal force amounted to about ·033 m.m.-m.g. units, or $\frac{1}{100}$th part of the total horizontal force. At St. Petersburg the change in the horizontal force amounted to ·04 m.m. m.g. units, or $\frac{1}{40}$th part of the whole horizontal force, and the total force was changed by about $\frac{1}{80}$th part of its full value. This second storm is remarkable for the very great diminution in the vertical force at St. Petersburg. From 5.30 p.m. to 12.30 (local time), the vertical force diminishes by ·06 (m.m. m.g.), the horizontal force in the same interval diminishing by ·04 (m.m. m.g.)

There are also remarkable points of agreement during the storm, as may be seen by a careful comparison of the curves, but the agreement between St. Petersburg horizontal and vertical force curves compared with Kew and Lisbon declination curves is remarkable about 4.30 p.m. and between 7 and 8 p.m., when the change in the horizontal force in about ten minutes at St. Petersburg amounted to ·027 m.m. m.g. units or $\frac{1}{60}$th of the horizontal force.

With the Lisbon declination curves there is some uncertainty, as the times of the beginning and end are not marked upon the tracing, and the time-scale does not appear to be quite the same as for the horizontal or vertical force curves.

Thus we see that the magnetic changes which take place at various points of the earth's surface at the same instant are so large as to be quite comparable with the earth's total magnetic force; and in order that any cause may be a true and sufficient one, it must be capable of producing these changes rapidly. They are so large that any cause which is shown to be incompetent to produce the earth's magnetism can hardly be held to account for such terrestrial magnetic changes. Since the large disturbances and the small disturbances do not follow totally different laws, but agree equally well all over the earth, in so far as they agree we must attribute them to the same cause.

In the third storm, on August 13th (see Plate XIII.), the general character of the disturbances is the same at St. Petersburg, at Kew, at Lisbon, and at Vienna, as shown by a comparison of the horizontal force as well as of the declination curves, and the vertical force needles are similarly affected at St. Petersburg and at Stonyhurst; but about 11.30 p.m., when the horizontal force at other European stations is considerably increased, the horizontal force at St. Petersburg is very greatly diminished, so that the record passes off the edge of the paper. The horizontal force at Zi-ka-Wei is greatly diminished, and at Melbourne is also diminished at the same time, the vertical force at St. Petersburg and at Stonyhurst being at the same time diminished to its lowest value during the storm. There are some very remarkable points of agreement between the St. Petersburg horizontal force and the Zi-ka-Wei declination and horizontal force curves, considering that the two places of observation differ nearly 30° in latitude, and are 6 hours apart in time. The Melbourne horizontal force curve also bears a very striking resemblance to the Zi-ka-Wei horizontal force curve, more especially from 11 p.m. until the end of the storm. The Melbourne declination curve inverted and the Zi-ka-Wei declination curve also have many characteristics in common. Taking the Mauritius declination curve which is only slightly disturbed, probably because the needle is not sufficiently sensitive, it is seen that the greatest disturbances are similar to and coincident in time with disturbances in the Zi-ka-Wei horizontal force curve. The similarity between the vertical force curves at St. Petersburg and at Stonyhurst is very striking, especially when it is considered that at Lisbon and Stonyhurst, two places nearer together, the vertical force curves have very few coincident and similar disturbances.

The following table contains the Comparative Scale Values for the curves drawn in the Plates.

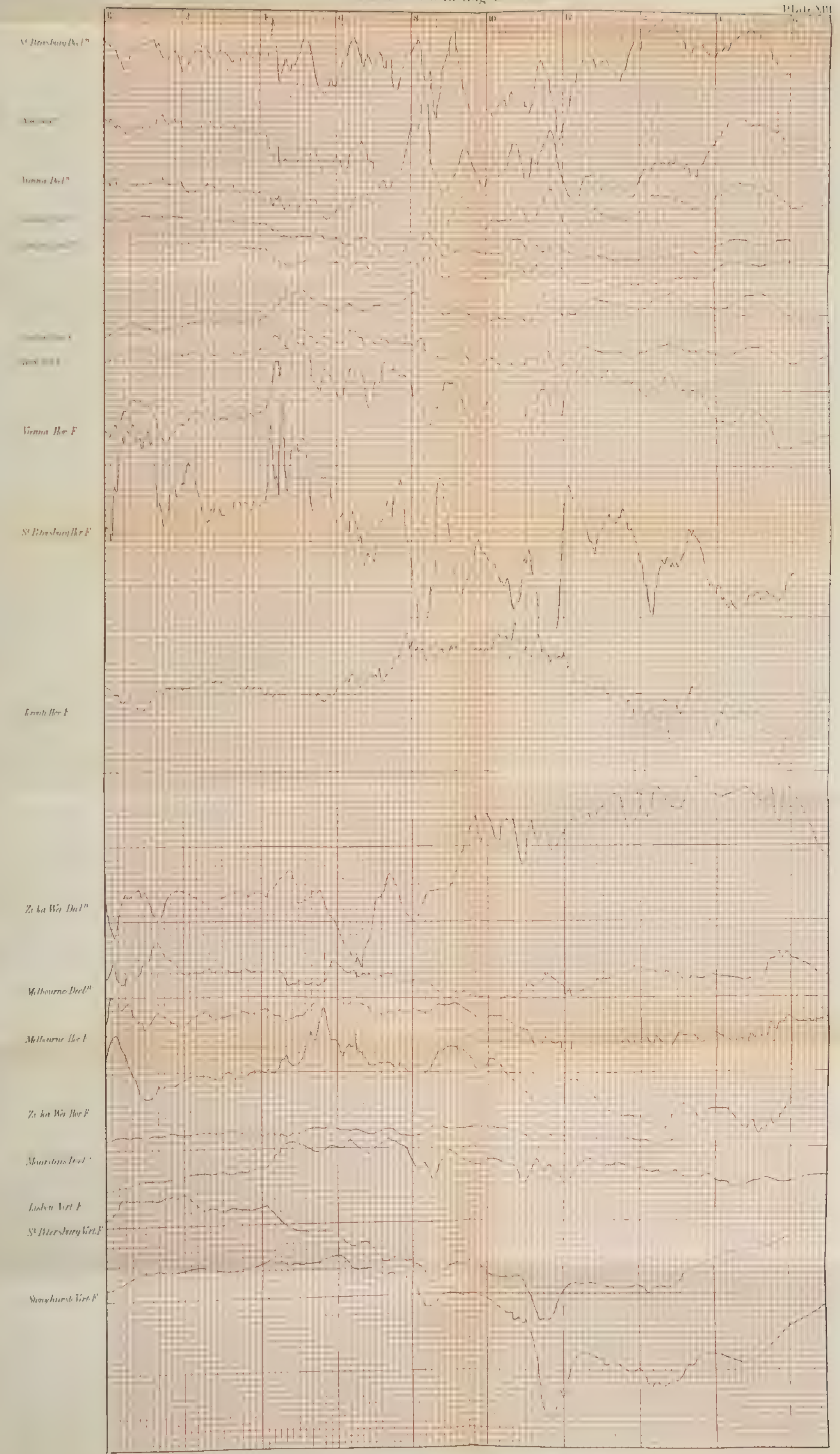
	Horizontal Force		Vertical Force	
	$\frac{\delta H}{H}$ for 1 mm.	δH	$\frac{\delta V}{V}$ for 1 mm.	δV
St. Petersburg	·00018	·00029	·00014	·00066
Zi-ka-Wei				
August 11 and 13	·000078	·00025	—	—
August 12	·000156	·00049	—	—
Vienna	·00025	·00051	—	—
Melbourne	·00028	·00066	·00012	·00067
Toronto	·00040	·00072	—	—
Kew	·00071	·00127	·00024	·00106
Bombay	·00045	·00167	·0024	·0030

St

COMPARISON OF MAGNETIC ELEMENTS.

1 a.m. to 7 a.m. Aug 13 14th 1880

Plate XIII



Illustrating Professor W. Grylls Adams's Paper on Magnetic Disturbances.

δH and δV are expressed in millimètre-milligrammes for 1 millimètre, or in centimètre-grammes for 1 centimètre, *i.e.* they are the values of a centimètre (a unit of length) of the ordinate, according to the C.G.S. system of units.

From this table it appears that the same absolute disturbance will produce changes in the ordinates of the St. Petersburg horizontal force curve, which are more than four times the corresponding changes in the ordinates in the Kew curve, and which are nearly six times the corresponding changes in the ordinates in the Bombay curve.

The scale-values in this table are the same as in the originals, except in the case of Zi-ka-Wei and Toronto. The values for δH in the original curves are ·00062 millimètre-milligrammes for Zi-ka-Wei and ·00058 for Toronto.

A comparison of the curves with the scale-values shows that at the beginning of the storm on August 11 the change in the horizontal force at Vienna was very nearly equal to the change at St. Petersburg, and about $1\frac{1}{2}$ times the change at Zi-ka-Wei; also the changes at Melbourne, at Zi-ka-Wei, at Toronto, and at Bombay are very nearly equal to one another, and amount to about ·0047 millimètre-milligrammes.

Thus the amount of the disturbance does not seem to increase with the latitude. Again, the changes occurring between 11.30 and 11.40 a.m. amount to about—

·016	mm.-mgr.	at St. Petersburg;
·013	„	at Vienna and at Zi-ka-Wei;
·010	„	at Kew and at Toronto, but in opposite directions;
·0084	„	at Bombay.

Thus the absolute value of the disturbance at Bombay is not much less than in higher latitudes, the flatness of the curve being due to the fact that the needle is not sufficiently sensitive. On comparing the curves with the table of scale-values, it seems clear that for magnetic storms the most satisfactory curves for comparison and for measurement are those which do not differ much in size from the Vienna curves, *i.e.* the most satisfactory scale-value is about ·0004 or ·0005 millimètre-milligrammes for 1 millimètre. When the scale-values are very much larger, as in the Kew and Bombay instruments, the needles are not sensitive enough to give the character of the disturbances, and when the scale-value is less than about ·0004 millimètre-milligrammes, the curves may have a very wide range, and are very liable to go off the edge of the paper.

Great differences of practice exist at different observatories; thus, at St. Petersburg and at Toronto, a curve with ordinates increasing upwards corresponds to decreasing horizontal force. This was also the case at Vienna in 1879; but, from a comparison of the curves for August 1880, it appears that a change has been made by which a curve with ordinates increasing upwards corresponds to increasing horizontal force. At all the other observatories a curve with ordinates increasing upwards corresponds to increasing horizontal force, and it would facilitate comparison if this rule were universally observed. In the Lisbon and Coimbra and in the Melbourne curves only the times of the beginning and end and one or two other points in the curve are determined; on this account some difficulty has been found in comparing them with the others. At other observatories, at every hour or at every two hours, the time is marked by an eclipse of the light for either two minutes, as in the case of Vienna, or four minutes, as at Kew, Stonyhurst, &c. The eclipse of the light at the *beginning* of every hour, or of every two hours, for two minutes, which is quite long enough to mark the time, might conveniently be adopted, and is better than an eclipse for a longer period, if it occurs in the middle of a storm. Also at Vienna only one curve is photographed on each sheet, and so the difficulty is avoided of having two or more time lines with the same hours not coincident with one another, and there is no confusion arising from curves crossing one another.

In the Plates the curves have been traced with great care, and set as accurately as possible to Greenwich mean time. They have been grouped so as to bring out prominently the common features running through them, with the object of supplying facts on which a theory of terrestrial magnetic disturbances may be firmly established.

During this August storm great difficulties were experienced in working the telegraph lines, in consequence of earth-currents, and from particulars with which I have been supplied by Mr. Preece, and from the earth-current photographic records taken at Greenwich Observatory on two separate wires running in a S.W. and a N.W. direction, for copies of which I am indebted to the Astronomer-Royal, it is possible to trace the connection between these magnetic storms and earth-currents.

The photographic records at Greenwich during this storm are bent opposite ways at the same time, so that when an earth-current is running on one line towards Greenwich, on the other the earth-current is away from Greenwich; thus, when there is an earth-current on the line from the S.W. towards Greenwich, there is found to be a current on the other line from Greenwich towards the N.W. If the current on these lines were absolutely equal it would indicate that the current in the crust of the earth was in a direction from south to north. If the current from the S.W. is greater than the current towards the N.W. it would indicate an earth-current in a direction more nearly inclined from S.W. to N.E. On comparing these photographic records with the earth-current records from Derby and Haverfordwest and other places, it appears that the general direction of currents during this storm was from about S.S.W. to N.N.E., with varying intensity, the agreement between the disturbances of the declination needle and the Blackheath and Greenwich photographic record (*i.e.* from S.W. to Greenwich), being very close and in the same direction at the same time. Earth-currents were very violent from 10.30 a.m. on the 11th to about 2.30 p.m., and again from 9 p.m. until midnight. They were violent on August 12, beginning at 11.30 a.m., the beginning of the second storm, and quieting down about 4.30 p.m., then beginning again at 7.30 p.m. and lasting until 9.30 p.m. Again on the 13th they were recorded as strong for about one and a half hours from 5 a.m., *i.e.* just at the end of the second magnetic storm.

The general direction of earth-currents as observed on telegraph lines, especially at Derby and Haverfordwest, as well as at the Greenwich Observatory, was from a S.W. to a N.E. direction. During the most violent phases of the magnetic storm, the earth-current photographic record at Greenwich failed in consequence of the rapidity and the extent of the swings of the galvanometer needle. Intimately connected with magnetic disturbances and earth-currents is the phenomenon of the Aurora or Polar Light, which is an electric discharge in the upper regions of the atmosphere. During the August storm, and also during another violent magnetic storm which took place on January 31 last, the aurora was well seen in England; it was also seen at St. Petersburg and as far east as Siberia. It does not appear to have been seen, although it was looked for, at Zi-ka-Wei in China by M. Dechevrens, the director of the Observatory, although the magnetic storm was so violent there that the horizontal force was suddenly changed by $\frac{1}{100}$th part of its total amount.

In his address before the British Association in 1863 Sir William Armstrong speaks of the sympathy between forces operating in the sun and magnetic forces on the earth, and notices a remarkable phenomenon seen by independent observers on September 1, 1859. 'A sudden outburst of light, far exceeding the brightness of the sun's surface, was seen to take place, and sweep like a drifting cloud over a portion of the solar surface. This was attended with magnetic disturbances of unusual intensity, and with exhibitions of aurora of extraordinary brilliancy. The identical instant at which the effusion of light was observed was recorded by an abrupt and strongly-marked deflection in the self-registering instruments at Kew. The magnetic storm commenced before and continued after the event.'

The daily and yearly periods of the magnetic changes, the change in the horizontal force depending on the sun's rotation on his axis, the agreement of the eleven-year period of magnetic disturbances, sun-spots, and auroras, show that the sun plays a very important part in causing or regulating both the regular and irregular magnetic changes.

We know so little as yet of the causes of the changes of the sun, and their connection with terrestrial phenomena, that we can hardly do more than ask what possible causes there are which could account for the effects which are observed. Can we suppose that the Sun is a very powerful magnet, and that a great alteration in his magnetism accompanies the production of the bright faculæ and the spots in his atmosphere? Such a change of magnetism would affect the magnetism of the earth, although the effect could not be very large, unless the sun is magnetized to an intensity much greater, even compared to his mass, than the earth is magnetized. Then, as there are tides in the seas around us, and probably in the earth's crust, so there are certainly very large tides in the ocean of air above us; and may not the sun and moon, by dragging this air towards them as the earth revolves, cause that friction between air and earth, and also that evaporation, which, together, may account for the presence of, and keep up the supply of, positive electricity in the air and negative electricity in the earth? Again, these tides in the atmosphere will cause the mass of it to lag behind the revolving solid earth, and at a height of thirty or forty miles we have a layer of air which, for air, is a comparatively good conductor of electricity. Here, then, we have not a lagging of the magnet behind the conductor, but a lagging of the conductor behind the magnet, and hence we may expect a current or a gradual heaping-up of electricity in the air in the opposite direction to the current in the earth's crust. Thus, whilst the tidal wave in the earth's crust would cause a current in a telegraph wire from the equator towards the poles, the regular tidal waves in the atmosphere would cause the gradual transfer of positive electricity in the atmosphere from the poles towards the equator. This transfer may be of the nature of a current of electricity or of a mass of air carrying a static charge of electricity with it; for, as Professor Rowland has shown that the motion of a static charge will produce magnetism, so we may expect, from the principles of conservation of electricity, that a change in the position of a magnet will, under such circumstances, produce motion of the static charge of electricity.

When the air becomes charged up to discharging point, then we may get the sudden discharges, such as the aurora in the air and the earth-currents in the earth ; and since the conducting layer of air approaches nearer to the earth in the colder polar regions—possibly within less than twenty miles of the earth's surface—it may be found that the discharge of the aurora may even take place from earth to air by gradual slow discharge, aided, as it may be, by the state of moisture, and by change of temperature, and other causes.

In addition to the European stations the principal Observatories for photographic registration of the magnetic elements are at Toronto, Zi-ka-Wei, Bombay, and Melbourne. The fact that there are so few such Observatories will be sufficient to show how important it is that there should be additional Magnetic Observatories—more especially in America, in the eastern parts of Siberia, and in the southern hemisphere. Practically we have to rely on one excellent Observatory (Melbourne) for the whole of the southern hemisphere. Seeing that the French Government have decided to establish a Magnetic Observatory at Cape Horn next year, where photographic records of the changes of the magnetic elements are to be taken, surely it is time that a fully-equipped Magnetic Observatory should be established at the Cape of Good Hope, where there is already an excellent Astronomical Observatory and a staff of observers ready to carry on the work.

On some applications of Electric Energy to Horticultural and Agricultural purposes, by C. Wm. Siemens, *D.C.L., LL.D., F.R.S., Mem. Inst. C.E.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

On March 1, 1880, I communicated to the Royal Society a paper 'On the influence of electric light upon vegetation, &c.,' in which I arrived at the conclusion that electric light was capable of producing upon plants effects comparable to those of solar radiation; that chlorophyl was produced by it, and that bloom and fruit rich in colour and aroma could be developed by its aid. My experiments also went to prove that plants do not as a rule require a period of rest during the twenty-four hours of the day, but make increased and vigorous progress if subjected (in winter time) to solar light during the day and to electric light during the night.

During the whole of last winter I continued my experiments on an enlarged scale, and it is my present purpose to give a short account of these experiments, and of some further applications of electric energy to farming operations (including the pumping of water, the sawing of timber, and chaff- and root-cutting) at various distances not exceeding half a mile from the source of power, giving useful employment during day-time to the power-producing machinery, and thus reducing indirectly the cost of the light during night-time.

The arrangement consists of a high-pressure steam-engine of six horse-power nominal, supplied by Messrs. Tangye Brothers, which gives motion to two dynamo-machines (Siemens D), connected separately to two electric lamps, each capable of emitting a light of about 4,000 candle-power. One of these lamps was placed inside a glass house of 2,318 cubic feet capacity, and the other was suspended at a height of twelve to fourteen feet, over some sunk greenhouses. The waste steam of the engine was condensed in a heater, whence the greenhouses take their circulating supply of hot water, thus saving the fuel that would otherwise be required to heat the stoves.

The experiments were commenced on October 23, 1880, and were continued till May 7, 1881. The general plan of operation consisted in lighting the electric lights at first at six o'clock, and during the short days at five o'clock every evening except Sunday, continuing their action until dawn.

The outside light was protected by a clear glass lantern, whilst the light inside the house was left naked in the earlier experiments, one of my objects being to ascertain the relative effect of the light under these two conditions. The inside light was placed at one side over the entrance into the house, in front of a metallic reflector to save the rays that would otherwise be lost to the plants within the house.

The house was planted in the first place with peas, French beans, wheat, barley and oats, as well as with cauliflowers, strawberries, raspberries, peaches, tomatoes, vines, and a variety of flowering plants including roses, rhododendrons and azaleas, all these plants being of a comparatively hardy character; the temperature in this house was maintained as nearly as possible at 60° Fahr.

The early effects observed were anything but satisfactory. While under the influence of the light suspended in the open air, over the sunk houses, the beneficial effects due to the electric light, observed during the previous winter, repeated themselves, the plants in the house with the naked electric light soon manifested a withered appearance. Was this result the effect of the naked light, or was it the effect of the chemical products—nitrogenous compounds and carbonic acid—which are produced in the electric arc?

Proceeding on the first-named assumption, and with a view of softening the ray of the electric arc, small jets of steam were introduced into the house through tubes, drawing in atmospheric air with the steam, and producing the effect of clouds interposing themselves in an irregular fashion between the light and the plants. This treatment was decidedly beneficial to the plants, although care had to be taken not to increase the amount of moisture thus introduced beyond certain limits. As regards the chemical products—carbonic acid and nitrogenous compounds—it was thought that these would prove rather beneficial than otherwise in furnishing the very ingredients upon which plant-life depends, and further that the constant supply of pure carbonic acid resulting from the gradual combustion of the carbon electrodes, might render a diminution in the supply of fresh air possible, and thus lead to economy of fuel. The plants did not, however, take kindly to these innovations in their mode of life, and it was found necessary to put a lantern of clear glass round the light, for the double purpose of discharging the chemical products of the arc, and of interposing an effectual screen between the arc and the plants under its influence.

The effect of interposing a mere thin sheet of clear glass between the plants and the source of electric light was most striking. On placing such a sheet of clear glass so as to intercept the rays of the electric light from a portion only of a plant—for instance, a tomato plant—it was observed that in the course of a single night the line of demarcation was most distinctly shown upon the leaves. The portion of the plant under the direct influence of the naked electric light, though at a distance from it of nine to ten feet, was shrivelled, whereas that portion under cover of the clear glass, continued to show a healthy appearance, and this line of demarcation was distinctly visible on individual leaves—not only the leaves but the young stems of the plants soon showed signs of destruction when exposed to the naked electric light, and these destructive influences were perceptible, though in a less marked degree, at a distance of twenty feet from the source of light.

A question here presents itself that can hardly fail to excite the interest of the physiological botanist. The clear glass does not apparently intercept any of the luminous rays, which cannot therefore be the cause of the destructive action. Professor G. G. Stokes showed, however, in 1853, that the electric arc is particularly rich in highly refrangible invisible rays, and that these are largely absorbed in their passage through clear glass; it therefore appears reasonable to suppose that it is those highly refrangible rays beyond the visible spectrum that work destruction on vegetable cells; thus contrasting with the luminous rays of less refrangibility, which, on the contrary, stimulate their organic action.

Being desirous to follow up this inquiry a little further, I sowed a portion of the ground in the experimental conservatory with mustard and other quick-growing seeds, and divided the field into equal radial portions by means of a framework, excluding diffused light but admitting light at equal distances from the electric arc. The first section was under the action of the naked light, the second was covered with a pane of clear glass, the third with yellow glass, the fourth with red, and the fifth with blue glass. The relative progress of the plants was noted from day to day, and the differences of effect upon the development of the plants was sufficiently striking to justify the following conclusions: viz., under the clear glass the largest amount of and most vigorous growth was induced; the yellow glass came next in order, but the plants, though nearly equal in size, were greatly inferior in colour and thickness of stem to those under the clear glass; the red glass gives rise to lanky growth and yellowish leaf, while the blue glass produces still more lanky growth and sickly leaf. The uncovered compartment showed a stunted growth, with a very dark and partly shrivelled leaf in the case of mustard, whereas tender-leaved plants, such as cress and salad, were completely destroyed.

It should be observed that the electric light was kept on from 5 p.m. till 6 a.m. every night except Sundays during the experiment, which took place in January 1881, but that diffused daylight was not excluded during the intervals, also that circulation of air through the dividing framework was provided for.

These results are confirmatory of those obtained by Dr. J. W. Draper in his valuable researches on plant-life in the solar spectrum in 1843,[1] which led him to the conclusion, in opposition to the then prevailing

[1] See *Scientific Memoirs* by J. W. Draper, M.D., LL.D.—Memoir X.

opinion, that the yellow ray and not the violet ray was most efficacious in promoting the decomposition of carbonic acid in the vegetable cell.

Having, in consequence of these preliminary inquiries, determined to surround the electric arc with a clear glass lantern, more satisfactory results were soon observable. Thus, peas which had been sown at the end of October, produced a harvest of ripe fruit on February 16, under the influence, with the exception of Sunday nights, of continuous light. Raspberry stalks, put into the house on December 16th, produced ripe fruit on the 1st of March, and strawberry plants, put in about the same time, produced ripe fruit of excellent flavour and colour on February 14. Vines which broke on December 26, produced ripe grapes of stronger flavour than usual on March 10. Wheat, barley, and oats shot up with extraordinary rapidity under the influence of continuous light, but did not arrive at maturity; their growth having been too rapid for their strength, caused them to fall to the ground, after having attained the height of about twelve inches.

Seeds of wheat, barley, and oats planted in the open air, and grown under the influence of the external electric light, produced, however, more satisfactory results; having been sown in rows on January 6, they germinated with difficulty on account of frost and snow on the ground, but developed rapidly when milder weather set in, and showed ripe grain by the end of June, having been aided in their growth by the electric light until the beginning of May.

Doubts have been expressed by some botanists whether plants grown and brought to maturity under the influence of continuous light would produce fruit capable of reproduction, and in order to test this question, the peas gathered on February 16 from the plants which had been grown under almost continuous light-action, were replanted on February 18. They vegetated in a few days, showing every appearance of healthy growth.

Further evidence on the same question will be obtained by Dr. Gilbert, F.R.S., who has undertaken to experiment upon the wheat, barley, and oats grown as above stated; but still more evidence will probably be required before all doubt on the subject can be allayed.

I am aware that the great weight of the opinion of Dr. Darwin goes in favour of the view that many plants, if not all of them, require diurnal rest for their normal development. In his great work on 'The Movements of Plants' he deals in reality with plant life as it exists under the alternating influence of solar light and darkness; he investigates with astonishing precision and minuteness their natural movements of circumnutation and nightly or nyctitropic action, but does not extend his inquiries to the conditions resulting from continuous light. He clearly proves that nyctitropic action is instituted to protect the delicate leaf-cells of plants from refrigeration by radiation into space, but it does not follow, I would submit, that this protecting power involves the necessity of the hurtful influence. May it not rather be inferred from Dr. Darwin's investigations that the absence of light during night-time involved a difficulty to plant life that had to be met by special motor organs, which latter would perhaps be gradually dispensed with by plants if exposed to continual light for some years or generations?

It is with great diffidence, and without wishing to generalise, that I feel bound to state, as the result of all my experiments, extending now over two winters, that although periodic darkness evidently favours growth in the sense of elongating the stalks of plants, the continuous stimulus of light appears favourable for healthy development at a greatly accelerated pace, through all the stages of the annual life of the plant, from the early leaf to the ripened fruit. The latter is superior in size, in aroma, and in colour to that produced by alternating light, and the resulting seeds are not at any rate devoid of re-germinating power.

Further experiments are necessary, I am aware, before it would be safe to generalize; nor does this question of diurnal rest in any way bear upon that of annual or winter rest, which probably most plants that are not so-called annuals, do require.

The beneficial influence of the electric light has been very manifest upon a banana palm, which at two periods of its existence, viz., during its early growth, and at the time of the fruit-development, was placed (in February and March of 1880 and 1881) under the night action of one of the electric lights, set behind glass at a distance not exceeding two yards from the plant; the result was a bunch of fruit weighing seventy-five pounds, each banana being of unusual size, and pronounced by competent judges unsurpassed in flavour. Melons, also remarkable for size and aromatic flavour, have been produced under the influence of continuous light in the early spring of 1880 and 1881, and I am confident that still better results may be realised when the best conditions of temperature and of proximity to the electric light have been thoroughly investigated.

My object hitherto has rather been to ascertain the general conditions necessary to promote growth by the aid of the electric light, than the production of quantitative results; but I am disposed to think that the time is not far distant when the electric light will be found a valuable adjunct to the means at the disposal of the horticulturist, in making him really independent of climate and season, and furnishing him with a power of producing new varieties.

Before electro-horticulture can be entertained as a practical process it would be necessary, however, to prove its cost, and my experiments of last winter have been in part directed towards that object. Where water-power is available, the electric light can be produced at an extremely moderate cost, comprising: carbon electrodes, wear and tear of, and interest upon apparatus and machinery employed, which experience elsewhere has already shown to amount to 6*d.* per hour for a light of 5,000 candles. The personal attention requisite in that case consists simply in replacing the carbon electrodes every six or eight hours, which can be done without appreciable expense by the under-gardener in charge of the fires of the green-houses.

In my case no natural source of power was available, and a steam-engine had to be resorted to. The engine of six nominal horse-power which I employ to work the two electric lights of 5,000 candle-power each, consumes fifty-six pounds of coal per hour, the engine being of the ordinary high-pressure type,—which, taken at 20*s.* a ton, would amount to 6*d.*, or to 3*d.* per light of 5,000 candles. But against this expenditure has to be placed the saving of fuel effected in suppressing the stoves for heating the greenhouses, the amount of which I have not been able to ascertain accurately, but it may safely be taken at two-thirds of the cost of coal for the engine, thus reducing the cost of the *fuel* per light to 1*d.* per hour; the total cost per light of 5,000 candles will thus amount to 6*d.*+1*d.*=7*d.* per hour.

This calculation would hold good if the electric light and engine-power were required during, say, twelve hours *per diem*, but inasmuch as the light is not required during the day-time, and the firing of the boiler has nevertheless to be kept up in order to supply heat to the greenhouses, it appears that during the day-time an amount of motive power is lost equal to that employed during the night.

In order to utilise this power I have devised means of working the dynamo-machine also during the daytime, and of transmitting the electric energy thus produced by means of wires to different points of the farm, where such operations as chaff-cutting, swede-slicing, timber-sawing, and water-pumping have to be performed.

These objects are accomplished by means of small dynamo-machines, placed at the points where power is required for these various purposes, and which are in metallic connection with the current-generating dynamo-machine near the engine. The connecting wires employed consist each of a naked strand of copper wire, supported on wooden poles or on trees without the use of insulators, whilst the return circuit is effected through the park-railing or wire fencing of the place, which is connected with both transmitting and working machines by means of short pieces of connecting wire. In order to insure the metallic continuity of the wire fencing, care has to taken, wherever there are gates, to solder a piece of wire, buried below the gates, to the wire fencing on either side.

As regards pumping the water, a 3 horse-power steam-engine was originally used, working two force pumps of $3\frac{1}{2}$ inches diameter, making thirty-six double strokes per minute. The same pumps are still employed, being now worked by a dynamo-machine weighing 4 cwt. When the cisterns at the house, the gardens, and the farm require filling, the pumps are started by simply turning the communicator at the engine station, and in like manner the mechanical operations of the farm already referred to are accomplished by one and the same prime mover.

There would be difficulty in this instance in stating accurately the percentage of power actually received at the distant station, but in trying the same machines under similar circumstances of resistance, with the aid of dynamometers, as much as sixty per cent. has been realised.

In conclusion, I have pleasure in stating that the working of the electric light, and the transmission of power for the various operations just named, are entirely under the charge of my head gardener, Mr. Buchanan, assisted by the ordinary staff of under-gardeners and field-labourers, who probably never before heard of the power of electricity.

Electric transmission of power may eventually be applied also to thrashing, reaping, and ploughing. These objects are at the present time accomplished to a large extent by means of portable steam-engines, a class of engine which has attained a high degree of perfection; but the electric motor presents the great advantage of lightness, its weight per horse-power being only 2 cwt., whilst the weight of a portable engine with its boiler filled with water may be taken at 15 cwt. per horse-power. Moreover the portable steam-engine requires a continuous supply of water and fuel, and involves skilled labour in the field, whilst the electrical engine receives its food through the wire (or a light rail upon which it may be made to move about), from the central station, where power can be produced at a cheaper rate of expenditure, for fuel and labour, than in the field. The use of secondary batteries may also be resorted to with advantage to store electrical energy when it cannot be utilised.

In thus accomplishing the work of a farm from a central-power station, considerable savings of plant and labour may be effected; the engine-power will be chiefly required for day work, and its night work, for the purposes of electro-horticulture, will be a secondary utilisation of the establishment involving little extra expense. At the same time the means are provided of lighting the hall and shrubberies in the most perfect manner, and of producing effects in landscape gardening that are strikingly beautiful.

Since writing the above my attention has been called to a very interesting Report entitled 'Researches on the Influence of the Solar Rays on the Growth of Plants' communicated to the Oxford Meeting of the British Association in 1847, by Mr. Robert Hunt, F.R.S., towards the end of which he gives the following as the conclusions arrived at.

1. Light prevents the germination of seeds.
2. Actinism quickens germination.
3. Light acts to effect the decomposition of carbonic acid by the growing plant.
4. Actinism and light are essential to the formation of the colouring matter of leaves.
5. Light and actinism, independent of calorific rays, prevent the development of the reproductive organs of plants.
6. The heat-radiations corresponding with the extreme red rays of the spectrum facilitate the flowering of plants and the perfecting of their reproductive principles.

On the Pressure of Wind upon a Fixed Plane Surface.
By Thomas Hawksley, *C.E., F.R.S.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

The recent failures of the Tay Bridge and other important structures during heavy gales of wind, have attracted much attention to the subject of this paper. The general solution of the problem may be thus briefly stated:—

Let v = the velocity of the current in feet per second.
h = the height through which a heavy body must fall to produce the velocity v.
w = the weight in pounds of a cubic foot of the impinging fluid [for atmospheric air on an average about 0·0765 lbs.]
g = 32, the coefficient of gravity.

Then $h = \frac{v^2}{2g}$; and since p, the pressure of a fluid striking a plane perpendicularly and then escaping at right angles to its original path, is that due to twice the height h [Daubuisson's 'Hydraulics'; Rouse's 'Experiments'] we have simply

$$p = \frac{wv^2}{g}$$

$$= \text{(for atmospheric air)}\ \frac{0{\cdot}0765v^2}{32}$$

$$= \left(\frac{v}{20}\right)^2 \text{ very nearly.}$$

From this easily remembered formula the following table of pressures is constructed :—

Velocities in feet per second	Velocities in miles per hour	Pressures in lbs. per square foot
10	6·8	0·25
20	13·6	1·00
30	20·4	2·25
40	27·2	4·00
50	34·0	6·25
60	40·8	9·00
70	47·6	12·25
80	54·4	16·00
90	61·2	20·25
100	68·0	25·00
110	74·8	30·25
120	81·6	36·00
130	88·4	42·25
140	95·2	49·00
150	102·0	56·25

In general only these, the maximum pressures, are required; but sometimes, as in the case of the inclined sail of a windmill or ship, or the roof of a building, the diminished pressure upon a surface placed obliquely to the *effective* current is needed: we have then

$$p = \left(\frac{v \sin \theta}{20}\right)^2$$

in which $v =$ the absolute velocity with which the air strikes the receding plane; and $\theta =$ the internal angle made by the obliquely placed surface and the direction of the impinging wind.

With regard to the phenomenon called 'a gust of wind,' nothing is known either as to its cause, or as to its exceptional but almost momentary velocity, or as to the extent of the area over which it temporarily operates; but it is, notwithstanding, certain that a wind-pressure of even 40 lbs. on the square foot is unknown in these islands, because, as may be readily shown, this intensity of pressure would have sufficed to overthrow most of the long-existing factory chimneys, to overset post windmills, and to scatter the greater number of the slighter built domestic and other structures which have nevertheless 'weathered many a storm,' and still remain intact.

It remains to make a passing allusion to whirlwinds, tornadoes, and waterspouts, all the results of spiral motions apparently produced in some obscure manner by electrical action. These phenomena are very rarely observed to occur on an important scale in these kingdoms. The powerful forces concerned in or generated by these erratic movements have never been measured, and consequently cannot be formulated; but it may be observed that, were they known, they could not be introduced with propriety into calculations of the strength of structures intended to have a commercial value, because of the extreme improbability of any particular structure falling within the range of their destructive effects. They are, in fact, within the legal category of 'Acta Dei.'

The conclusion of the author of this paper, therefore, is that for structural calculations a maximum wind-pressure of 40 lbs. per square foot may be very safely adopted, notwithstanding some reported anemometrical observations to the contrary.

With regard to these observations the author remarks that the instruments in use are little better than philosophical toys, and that, in general, they afford no direct, comparable, or reliable indications of either velocities or pressures; and that they are often so injudiciously placed as in some instances to record the effects of combined and, therefore, locally accelerated currents; whilst in other instances, they record only the effects of obstructed and, therefore, locally retarded currents.

As the acquisition of accurate data is of great and increasing importance, the author suggests that the British Association, and other learned societies interested in physical investigations, should unite in providing the necessary funds and observers for the purpose.

On the Island of Socotra. By Bayley Balfour, *Sc.D., M.B., Regius Professor of Botany, University of Glasgow.*

[A communication ordered by the General Committee to be printed *in extenso* among the reports.]

The island of Socotra lies off the N.E. corner of Africa in lat. 12° 19′ to 12° 42′, and long. 53° 20′ to 54° 30′. Its extreme length from east to west is about 72 miles, and its breadth about 22 miles.

From Cape Guardafui 140 miles, it is a little more distant from the Arabian Coast (about 500 miles from Aden), and still further away from the Indian Peninsula.

It is the most easterly elevation of land on a coral bank lying to the N.E. of Africa, upon which, between it and Cape Guardafui, other islands (Abd-al-Kuri, Kal Farun, Samheh and Darzi—known commonly as The Brothers, and Saboynea) of smaller size occur. On no part of this bank is the depth of water over 200 fathoms, but between it and the African coast is a channel reaching 500 fathoms. Around Socotra is a narrow coral reef.

Perhaps no island of like extent, and lying, as one may say, on the threshold of civilisation, has remained in later times so generally unknown as Socotra. Situated on the highway of traffic to the East by way of Suez and the Red Sea, it is almost invariably sighted by steamers making for or from the Gulf of Aden, and thus to those who have passed along this route, its locality, or at least its name, will be known. To the scientific world it has been familiar as the country of a kind of aloes, the designation of which as Socotrine, has by some been traced to the name of the island. But to the majority of people its existence and its name are alike unknown, or at most it is associated in a vague sort of way with the East Indies.

The causes for this are not difficult to discover. The extreme outlying land in this region of the Indian Ocean, the island is exposed to the full blast of the monsoons, however they blow, and possessing no harbour in which a ship can at all times ride safely at anchor, it offers no inducements to ships seeking shelter. Then the currents which sweep past its shores run with considerable force into the Gulf of Aden, and there have been several shipwrecks on it, as well as on the African coast adjacent—the high hills of the island being easily mistaken for the mainland, and *vice versâ*—and navigation in its vicinity is altogether somewhat hazardous. It is not surprising, therefore, that passing vessels avoid the island as much as possible. Moreover, too, the want of intercourse with the island, and consequent ignorance regarding its inhabitants, have given currency to various rumours not favourable to their character, which, though quite unwarranted, yet have had their influence in preserving Socotra as a virgin and unexplored island in the pathway of civilisation.

Its position on the direct route to India is one of far too much importance to have allowed its remaining so neglected had any natural advantages obtained, permitting of its being utilised, or had there been no obstacles. Strategically valuable as is Aden, our station in this region, its barren waterless soil would place it at a great disadvantage, compared with an island possessing a rich soil and plentiful water-supply, such as Socotra, did it possess the other elements necessary for becoming a military station. But it has been tried and found wanting. Its history shows how at various periods its importance has been recognised, and certainly its present backward condition can hardly be ascribed to want of attempts to settle or to colonise it.

Its history is one of considerable interest. I do not purpose here to give in detail an account of the early history of the island. Suffice it that I briefly notice some of its leading vicissitudes up to the time when our expedition was first projected at this Association. The island seems to have been known to Europeans at an early period under the name of *Dioscoris* or *Dioscorida*,—a name traced by some to a Sanskrit root signifying 'abode of bliss'; by others to two Arabic words meaning 'island of dragon's-blood' (*kâtir* being the Arabic name for this gum). The author of the Periplus of the Erythrean Sea refers to it as a desolate island inhabited by a mixed population of Arabs, Indians, and Greeks, all speaking Greek, who had come thither in search of grain, and carried on a trade with the West Coast of India and with Mokha. The island is frequently mentioned by the early Arab geographers, who account for the Greek population by the story, which Colonel Yule considers a myth, that Alexander the Great, acting on the advice of Aristotle, settled an Ionian colony there, in order to cultivate the aloe. They further state that the Greeks and other inhabitants were converted to Christianity, and that clergy from Persia regularly visited the island. The population at this time, a few centuries after the Christian era, is put down by some at as much as 10,000, the majority of whom are described as Nestorian Christians and pirates.

In the time of Marco Polo, towards the end of the thirteenth century, the island was a metropolitan see of the Nestorian Church. Many ships visited the island, all vessels for Aden touching there, and the trade was mainly in ambergris, cotton stuffs, and salt fish. The people had the reputation of being enchanters, and of being able at will to raise the wind, to bring back ships, and to produce storms and disasters.

Although so mixed a population lived on the island, yet from the earliest times it appears to have been under the rule of the Mahra tribe, dwelling on the opposite side of Arabia, whose sultan or sheikh lived at Keshin.

In 1503 Fernandez Pereira discovered it for the Portuguese, at which time an Arab sheikh lived in a fort at Zoko (modern Suk), the then capital of the island; but it was not until 1507 that Tristan da Cunha and Albuqerque captured the island for the Portuguese. After four years' occupancy the Portuguese retired from the island, leaving abundant traces of their presence. The remains of a fort on Hadibu plain, and at various places on the S. and S.W. sides of the island, are most substantial ruins. Besides that their influence is possibly seen in such names of places as Derafonta and Feraigey, the name of one of the ruined forts, which may be Feringee. And indeed the dialect of Socotra may, it is thought by some, owe part of its peculiarity to a Portuguese basis. Moreover, at the present time, a large section of the inhabitants of the hill-region of the island claim direct descent from the Portuguese. About this date the character of the Christianity had somewhat changed, and they professed the doctrines of the Jacobite sect.

The evacuation by the Portuguese allowed a return of the Sultan of Keshin, and in his hands it has ever since remained, with the exception of a short occupancy on three several occasions by a foreign race—in 1538 by the Turks, in 1800 by the Wahabbees, and by the British from 1834 to 1839.

Although the ships of the East Indian Company frequently called at the island during the seventeenth century, some meeting with a friendly reception, others finding the reverse, and carried on a small trade in aloes and dragon's-blood (the stormy weather seems always to have been a source of dread), it was not until the year 1800 that affairs in the East directed the attention of the British Government to Socotra as a desirable possession, and the Commander of the naval station in that region was directed to seize it. This was not done, and it was not until 1834 that the necessity for a coaling station induced the Indian Government to survey the island. This was accomplished by Captain Haines and Lieutenant Wellsted, and the result of the survey being satisfactory, the Government attempted to buy the island, but failing to do so it was seized in 1835 by Indian troops. Aden having been taken in 1839, and being more suitable as a coaling dépôt, Socotra was abandoned.

The exploration of the island by Wellsted supplied us with the first, and indeed until now only detailed account of the island, its people, and productions.[1] The only available chart at present is the one made during this exploration, and it is most imperfect.

After the abandonment by the British in 1839, there is no record of Europeans visiting regularly the island. An occasional shipwreck brought it into notice, but it was not until 1876 that a prospect of the island being occupied by another power caused the British Government to turn attention to Socotra, with the result that in that year a treaty was concluded with the Sultan, by which he binds himself, and his heirs and successors, 'amongst other things, to protect any vessel, foreign or British, with the crew, passengers, and cargo, that may be wrecked on the island of Socotra or its dependencies, and he receives an annual stipend of 360 dollars for this.' The other things, it is understood, include a promise never to cede Socotra to a foreign power, or to allow a settlement on it without consent of the British Government. Thus the Sultan becomes a feudatory of Britain.

The attention of naturalists had long been directed to Socotra as a field for investigation whence rich results might be obtained, and Captain Hunter, who had visited the island in connection with the concluding of the treaty just mentioned, having brought back most encouraging accounts, Dr. Sclater in 1878 brought the matter prominently before this Association. A certain amount of money was obtained, mainly through his exertions, and a committee appointed to take steps for the exploration

[1] See *Journ. Roy. Geogr. Soc.*, vol. v.

of the natural history of the island. Various causes delayed the sending out of the expedition, and it was not until January, 1879, that I left this country, returning again in April, having spent, with two companions—Lieutenant Cockburn, 6th Royals, whose regiment was at Aden, and Alexander Scott, a gardener from the Royal Botanic Garden, Edinburgh, who accompanied me from England—nearly seven weeks on the island. At the meeting of this Association at Swansea last year, a report of the proceedings of the expedition was read, and is printed in the Association Reports. At that time the collections brought home were only in course of distribution for examination. Now a certain portion of them has been worked out, although the whole is not completed, and I purpose to-day to lay before the Association a brief account of the island as we saw it, and the results of our investigations so far as they have been carried out. Ere doing so I have one remark to make. Although so long a period elapsed between the evacuation of the island by the British and the date of our expedition last year, yet we have already been followed to the island (though the fact of our visit was not known to them) by the German traveller and botanist Dr. Schweinfurth, and some companions. They went in early spring of this year, and returned in May, having had, unfortunately, bad voyages both going and returning. Thus, after an interval of forty years, Socotra has been visited in two successive years by exploring parties. But what I desire to make public just now is this, that Dr. Schweinfurth, on learning that I had been to Socotra, at once offered to send to me his botanical collections, to be worked up along with my own—an act of generosity which I think deserves the fullest recognition, and which will enable me to bring out a much more complete account of the botany of the island.

The surface features of Socotra at the present time are those of an island mountainous in the extreme. The shore line on its southern aspect is, as the map shows, a tolerably continuous one, unbroken by deep inlets or bays. On the northern side occur a few shallow bays at the mouths of the streams, which afford the only anchorage to be obtained around the island, but no one of them is safe at all seasons of the year. On all sides the hills rise with considerable abruptness, over a wide area forming bold perpendicular cliffs of several hundred feet in height, whose base is washed by the waters of the Indian Ocean; but at other places leaving plains varying in breadth up to as much as five miles between their base and the shore. On the south side of the island is the largest of these shore plains—Nogad—which, extending nearly the whole length of the island, is for miles covered with dunes of blown sand. On the north these plains occur chiefly at the mouths of the streams, and are the sites of the only places which may be called towns.

The internal hilly part of the island may be roughly and shortly described as a wide undulating and intersected limestone plateau of an altitude averaging 1,000 feet, which flanks on the west, south, and east a nucleus of granitic peaks approaching 4,000 feet high. The whole of this hilly region is deeply cut into by ravines and valleys. These in the rainy season are occupied by roaring torrents, but the majority of them remain empty during the dry season. There are, however, many perennial streams on the island; especially in the central granitic region, where amongst the hills the most charming bubbling streams, dashing over boulders in a series of cascades, or purling gently over a pebbly shingle, make it hard to believe that one is in such proximity to the desert region of Arabia. Few of the perennial streams reach the shore in the dry season—most of them are fiumaras.

The eastern end of the island is most destitute of water. Here in the dry season are no rivers, and, springs being rare, it is the most arid region.

Igneous, metamorphic, and sedimentary rocks compose the island. The fundamental rock is granitic. This crops out, as I have mentioned, towards the middle of the island, forming a series of bare pinnacles and crags, projecting, with singularly fantastic look, from the plateau below. This rock also shows on the slopes of the valleys and ravines below the compact limestone which caps it and forms the surface rock of the hill plateaux. This limestone attains in places, as seen on the cliff faces, a thickness of two or three hundred feet. Superficially over wide areas it is rotted and broken into a jagged surface, over which progression is by no means easy, while at other spots it forms broad, smooth slabs. A shaley rock and coarse-textured purple sandstone, in beds dipping at all angles, crop out in the valleys and on the shore, whilst forming the shore-plains and the bases of the valleys is a recent breccia and conglomerate. Cutting through all these rocks and altering them to a considerable extent, occur dykes and extensive masses of doleritic rocks and felstones, which vary much in texture.

Professor Bonney, who is working out the rock specimens, tells me he has nearly completed his report, and we may therefore soon hope for more definite knowledge of the geology of the island.

The soil resulting from such petrological conditions is correspondingly varied, correlated with which is a varying character in vegetation and scenery.

In the valleys on the banks of the streams, especially in the granitic region, a deep rich red soil is found, and where there is water perennially it is covered by a luxuriant growth. As the limestone composes the greater part of its superficies the plateau appears barren. Where, however, the limestone has rotted, a series of nooks and crevices occur, in which, where a soil has collected, an *Aloe*, *Kalanchoe*, or other succulent finds a congenial habitat. But upon the limestone plateau, especially at the eastern and western ends of the island, occur depressions varying in width from some hundred yards up to a mile or more, girt on every side by the cavernous limestone cliff, with perhaps a narrow outlet through it at one or more points. These, which have all the appearance of lagoons, or at least of enclosed water-basins, are floored now by a rich red soil on which a crop of coarse grass, small herbs, and low trees vegetates. On the shore-plains the soil is light and sandy.

In its climate Socotra contrasts favourably with the adjacent shores of Arabia and Africa.

During the N.E. monsoon, from October to April, it is cool. January and February are the most pleasant months. But during the rest of the year it is exceedingly disagreeable. Rain falls twice in the year, at the changes of the monsoons, at which times the stream-courses are filled with mighty torrents. The temperature of course varies much with the altitude, and one may pass in the course of a few hours from the tropical heat of the shore plains to the cool temperate air of the mountain ranges. The average temperature on the plains in January is said to be about 70°, but in the hotter months it is as much as 86°. But on the plateau the temperature at nights often goes down to 52°. The higher peaks are, at least in the cool season, frequently enshrouded in mists, and at night very heavy dews fall. The climate on the hills is very healthy; but on the plains, especially at the changes of monsoon, fever is prevalent.

Of zoological features one of the most striking is the paucity of indigenous mammals. The antelopes and rodents of the adjacent continents are absent from Socotra, and there are but two mammals indigenous: a bat—of which, unfortunately, we did not obtain a specimen—and a civet cat. Rats and mice occur in the villages. Of the cassowary, mentioned by Wellsted, we saw and heard nothing. Birds are plentiful, so are lizards, and there are some snakes. The rivers are stocked with fish, and in them crabs are also found in abundance. Land mollusca are, as might be expected, frequent, and the whole island teems with insect life.

Our collections have been pretty nearly fully worked out. Mr. Sclater and Dr. Hartlaub have done the birds, Dr. Gunther has taken the snakes, and Mr. Blanford the lizards. The shells have fallen to Colonel Godwin-Austen, and Mr. Butler and Mr. Waterhouse have respectively worked out the Lepidoptera and Coleoptera; all their results being published in the 'Proceedings of the Zoological Society' for 1881. Though the collections are very fragmentary, yet they present features of interest, and show that whilst the fauna of Socotra possesses a fair amount of individuality, it is distinctly African in character. The specimens are too few in number to allow an estimate of the extent of the endemic fauna to be made, nor will that be practicable, as Mr. Sclater points out, until we learn something more of the zoology of the African coast around Cape Guardafui, which at present is almost unknown. The conclusions, however, that may be drawn from our present knowledge of the fauna of Socotra may be best expressed in the words of Colonel Godwin-Austen when speaking of the affinities of the land mollusca: 'There is strong evidence that the island was once directly connected with Madagascar to the south. We know the great antiquity of that island, and it is not unreasonable to suppose that in Socotra, the Seychelles, Madagascar, and Rodriguez we have the remnants of a very ancient, more advanced coast line on this western side of the Indian Ocean, which line of elevation was probably continuous through Arabia towards the north. With an equally advanced coast on the Indian side, the Arabian Sea would under these conditions have formed either a great delta or a narrow arm of the sea, into which the waters of the Indus and Euphrates drained. Such conditions would have admitted the extension of species from one side to the other, which the later and more extensive depression of the area, as shown in Scinde, afterwards more completely shut off.'

Of domesticated animals there are on Socotra—cattle, sheep, goats, camels, and asses. Old voyagers speak of horses being used, but there are none now. The cattle are small and have no hump. Immense herds are found at the east end of the island. The sheep are all fleeced, but there are none of the Berbera kind. Of goats there are some in a wild condition. The camels are much smaller than those at Aden and elsewhere in Arabia, and are able to climb like goats; many are kept for milking. Asses roam wild in herds all over the island.

The vegetation of the island varies in aspect with the character of the rocks. Starting from the shore one finds no representative of a marine phænogamic vegetation, although in the stagnant brackish waters at the mouths of the streams naiads occur. The coast is not favourable for seaweeds, being too shingly and sandy. On the dry sandy plains the vegetation typical of the desert regions on the mainland reigns. Small-leaved, stunted, and woody bushes and herbs, often so rigid as to become spiny, or fleshy plants without foliage-leaves prevail. Leaving the plains, and passing to the hill slopes and valleys, plant life is more vigorous, but in no place sufficiently so to call for the designation of forest, nor is there anything in the way of fine timber. But in the valleys, wherever there is any degree of moisture, small trees of some 20 to 25 feet, with smaller shrubs packed so densely as to exclude the light from above, linked together by far-reaching lianes, and underlain by a thick underscrub of fern and herb, make an almost impenetrable thicket, and produce a verdure quite tropical in its luxuriance. Once out of the valleys upon the plateaux and the scene is essentially different. Wide barren stretches of grey limestone extend on every side unrelieved, save by an isolated Dracœna, or tree Euphorbia of stiff erect habit, looking like the remnant of the vegetation of some old geological epoch; or where a lake-like depression, with its brown earth sparingly coated with green herbage, intervenes. And again, reaching the higher altitudes on the granitic range, the vegetation impresses one at once with its subtemperate character. The arborescent type has almost entirely disappeared. Twiggy, narrow-leaved herbs form a dense deep carpet on the soil, interrupted here and there by a protruding lichen-covered boulder, and for all the world like the covering of heather on a Scottish moor; whilst within the shade of the boulders, or in the moisture of the overhanging cliffs in the ravines, bright green herbs nestle in beds of liverwort and moss, so that it would require no very great effort to believe one was exploring an Alpine crag in a temperate region.

Aromatic odours are a marked feature of many plants, and also the occurrence of gums and resins, which in some cases form natural exudations in the form of tears. The common desert characteristics of a glaucous grey colouration or a hairy pubescence mark also many of the plants on the shore-plains and on the plateaux.

I shall not give any statistics regarding the flora, nor shall I attempt any detailed account of its affinities at the present. Our collections, amounting to about 700 species, of which 550 at least are Phænogams, are only in course of being worked out, and I am daily expecting a consignment of this gathering from Schweinfurth, which he tells me includes probably 200 species, that we did not obtain, and I consider it better therefore to delay until the materials for the estimation of the whole flora, as we are able to know it, are at hand.

The flora is, as you will readily believe, a pretty extensive one. There is in it a goodly number of cosmopolitan and tropical weeds, but there is a fair proportion of endemic genera and species. The orders most abundantly represented appear to be Leguminosæ and Gramineæ, closely followed by Compositæ, Acanthaceæ, Cyperaceæ, and Euphorbiaceæ. There is a fair number of ferns, a few orchids or palms, whilst of cellular Cryptogams lichens are exceedingly abundant.

Of individual plants interesting for various reasons, let me merely mention a few,—and firstly, on morphological grounds, may be noticed the 'Camhane' tree, a new genus of Cucurbitaceæ. This plant differs from the ordinal characters in being a tree with a stem often four or five feet in diameter at the base, rapidly tapering, and forming a very soft juicy wood. Another plant of interest, on morphological grounds, is a small tree bearing a fruit like a pomegranate, but instead of having the double row of carpels characteristic of the true *Punica granatum*, there is but a single whorl. Can this then be the primitive type of the Pomegranate? Another morphologically interesting plant is a Menisperm, a *Cocculus*, which differs from the ordinal type in being a hard erect undershrub, with cladodes and short spiny branches.

Gum and resin-producing plants are numerous. The most interesting of these is the dragon's-blood tree, *Dracæna Cinnabari*. The dragon's-blood of commerce at the present time is, as is well known, the product of *Calamus Draco* of Sumatra. But the Socotran gum is the old κινναβαρι mentioned by Dioscorides. It is known on the island as 'edah'; amongst the Arabs it is 'kâtir.' The plant is endemic, nearly allied to the *D. Draco* of Teneriffe. From the other gum-producing species, *D. Ombet* of Abyssinia and *D. schizantha* of Somali-land, of which we have as yet but imperfect knowledge, it is apparently quite distinct. The gum exudes in tears from the stem of the tree, and is collected after the rains; the gatherer chipping off the tears into goat-skins. There are three forms in which the gum is exported. Of these 'edah amsello,'—the tears as they exude from the tree—is the purest and most valuable form; 2½ lbs. fetch one dollar. The second-best kind is called 'edah dukkah.' It consists of the small chips and fragments of the tears which have been broken off in separating the gum-tears from the tree, or by attrition. It sells at one dollar for 4 lbs. The cheapest is the 'edah mukdehah,' which brings a dollar for 5 lbs., and is very impure. It is in the form of small flat-sided masses, and consists of fragments of the gum and refuse of the gatherings melted together into a flat cake, and then broken up into smaller portions.

Another most important gum-producing plant on the island is *Aloe Perryi*, which yields the 'Socotrine Aloes' of commerce. The gum is known as 'tâyef' by the natives; the Arabs call it 'sobr.' Although this kind of aloes has been so long known, and has the reputation of being finer than either Barbadoes or Cape aloes, it is only within the past few years that the character of the plant has been made known. It grows abundantly on the island, especially on the limestone plateaux. The collection of the gum is a very simple process, and can be accomplished at any season. The collector scrapes a slight hollow on the surface of the ground in the vicinity of an aloe-plant, into which he depresses the centre of a small portion of goat-skin spread over the ground. The leaves of the aloe are then cut and laid in a circle on the skin, with the cut ends projecting over the central hollow. Two or three layers are arranged. The juice, which is of a pale amber colour with a sweet, slightly mawkish odour and taste, flows from the leaves into the goat-skin. After about three hours the leaves are exhausted; the skin is removed from beneath them, and the contained juice transferred to a mussock. Only the older leaves are used. The juice thus collected is of a thin watery character, and is known as 'tâyef rhiho,' or watery aloes. In this condition it is exported to Muscat and Arabia, and sells for three dollars the skin of 30 lbs. By keeping, however, the aloes changes in character. After a month the juice gets, by loss of water, denser and more viscid; it is then known as 'tâyef gesheeshah,' and is more valuable—a skin of 30 lbs. fetching five dollars; whilst in about fifteen days more—that is, about six weeks after collection—it gets into a tolerably hard solid mass, and is then 'tâyef kasahul,' and is worth seven dollars a skin of 30 lbs. In this last condition it is commonly exported. Although this production is so easily obtained, yet its collection is most preçarious, and, indeed, is only resorted to by the inhabitants when, from want of rain, the pasturage is not sufficient for the cattle and sheep, and thus milk is scarce. In good seasons, when there is abundance of milk, and they are able to make ghi sufficient for their needs, very little aloes is obtained.

Of other gum-producing trees, a *Boswellia* yielding a kind of myrrh, the 'Ameero;' some *Balsamodendrons* yielding a poor 'olibanum;' and an *Odina* yielding a false myrrh, may be mentioned, as also an *Acacia* affording a very good gum.

Of plants striking as having brilliant flowers may be noted the *Adenium*, from which Aden derives its name; a tuberous *Begonia*, which will shortly be introduced into horticulture; a fragant *Crinum*, species of *Ruellia*, *Jasminum*, &c.

There is, as I have said, no forest on the island, and yet there is one small tree, or large shrub, which may be of some value commercially. It is the 'metayne,' a kind of box-tree, *Buxus Hildebrandti*. It was first found by Hildebrandt on the Somali-land hills. It forms a hard, compact wood, and, I doubt not, might be used for many of the purposes for which boxwood is so valuable at the present time. It is abundant on the island, and Hildebrandt reported it very common in Somali-land. I did not bring home sufficient specimens to allow of an experimental trial of this as a material for wood-cuts or other purposes. I learn from Dr. Schweinfurth, that he has sent some to Berlin to be tried in this way. Should the wood prove serviceable, it requires no special mention to indicate how valuable this product may become, in view of the exhaustion of the boxwood forests (of which we hear so much) in the S.E. of Europe.

Many plants are used on the island for the purposes of dyeing. But of these the only one that need be here referred to is the orchella weed, (*Rochella tinctoria*.) Occurring in abundance, it was formerly exported in great quantity. It is known as 'shennah.'

Few wild plants yield edible fruits; the jujube is abundant, and there is the tamarind and the bitter orange.

Briefly to summarise in general terms our knowledge of the Socotran flora, we may say it is essentially that of a continental island, and presents features indicating a considerable antiquity. The relative proportion of families to genera and of genera to species, is large. Annuals are few in number. In its characteristics it combines those of a dry and arid region with those of a moister and cooler region. Its individuality is great, and its affinities are mainly African, the closeness of relationship amounting to actual identity between many most peculiar and typical plants. And this affinity extends not only into the flora of the adjacent coast-line of Guardafui and Somali-land, of which, unfortunately, our knowledge is at present small, but still farther west into Nubia and Abyssinia, and (increasing tenfold the interest of the flora) reaches also southwards through Madagascar to the Cape, with the flora of which region there are some strong and very marked connections. Arabian relationships are present in the flora, nearly all the Aden plants being represented; but, unfortunately, beyond the flora of Aden we know very little of the vegetation of the adjacent Arabian region. Nor are more Eastern affinities wanting, for types of the North Indian region have representatives in the flora.

Our president, Sir Joseph Hooker, in the able and interesting address to which we listened on Thursday last, referred to the herbarium brought from Central Africa by Mr. Joseph Thomson, and remarked that 'it contained many of the endemic genera and even species of the Cape of Good Hope'—a fact most interesting as showing the prescience of a suggestion made many years ago by Sir Joseph Hooker 'that the South African flora has once been continued along the highlands of East Africa from Natal to Abyssinia.' Mr. Baker, too, on Friday read a most valuable paper on the flora of Madagascar, in which he pointed out the marked African affinities of that island, and its connection with the Cape and Central African forms.

And now from Socotra we learn the same story, and are therefore forced to the conclusion that we have here a remnant of an old African flora, of which, at the present day, the Cape is the southern, Abyssinia the northern, and this, along with Madagascar, the eastern extension.

The botanical evidence, it will be seen, bears out in a most emphatic manner the conclusions founded upon the fauna. From its geographical position one would *à priori* be led to regard Socotra as an outlier from the African continent, separated in the progress of cosmical change. The whole natural history of the island—geology, zoology, and botany —bears out this view.

Of plants cultivated on the island the most important is the date-palm. Every stream on the island is lined by groves of them, and the fruit is used, both ripe and unripe. Melons are grown, as also small onions. Little cereal culture is indulged in. Here and there, on the hills beside a stream, a small enclosure of 'bombé' (jowari) may be seen, but the inhabitants are too lazy to cultivate to any extent, the watering requiring too much labour. Only in one spot was there observed an attempt at irrigation.

Our expedition was essentially a botanical one, and the time at our disposal being limited, many points of interest regarding the people and their mode of life could not be investigated. But the island does possess great ethnological interest, as its history will have shown you, besides the somewhat melancholy interest which, as Colonel Yule remarks, attaches to a people once Christian, and now lapsed into a semi-barbarous condition. I may, however, shortly bring before you some facts regarding the inhabitants.

The extent of population it is impossible to estimate, as so many people live in caves, and one only occasionally came across the wandering inhabitants of the hill region.

In speaking of the people, the dwellers on the shore must be distinguished from those on the hills. The former, who are a mixed population of Arabs, Indians, and Africans of various tribes, live in small towns. Of these at present the chief is Tamarida, on the extensive Hadibu plain at the base of the Haggier range of hills. It is the capital of the island, and consists of a number of stone and lime houses, of the ordinary construction seen in Arabia, all plastered outside of a dazzling white, and surrounding a large one, which is the Sultan's palace. Around the town is a dense date-grove. There is a mosque and well-filled graveyard in the centre of the town. The number of inhabitants is set down at about 400. Kadhab is another village, lying on a sandy spit east from Tamarida. The houses here are of the same character as at Tamarida, and there is a mosque. Gollonsir, at the west end is the penal settlement, and has but few houses. Formerly the capital of the island was Suk, at the east edge of the Hadibu plain, but it was destroyed. There are numerous small villages all along the coast line, but the three mentioned are the chief towns.

The occupation of the residents in these villages is mainly fishing. They cultivate small tracts of ground near their houses, but are, as a rule, idle. The population too is somewhat changing, many going off in trading buggalows to Zanzibar or the Arabian coast.

The inhabitants of the hills, 'Bedouins,' as they are called, are very different people. They are regarded as the aborigines of the island, and alone possess any great interest ethnologically. They are mostly troglodytes, but here and there live in small huts, with stone and lime walls and roofed with date-palm leaves. They are a most peaceable race of people, and are divided into numerous families belonging to a few principal tribes. A study of these tribes would well repay the time and trouble spent upon it. Captain Hunter says: 'The "Karshin," who inhabit the western end of the island, claim to be descendants from the Portuguese. The "Momi," who reside in the eastern end of the island, are said to trace descent from the aborigines and the Abyssinians; whilst the "Camahane," who live in Haggier and the hills above the Hadibu plain, claim to arise from the intermarriage of the aborigines with the Mahri Arabs from the opposite coast. Whatever be their origin, certain is it that the hill people have a very distinct appearance. Many of them are tall and finely made, the men with broad shoulders, lean flanks, and stout legs, reminding one very forcibly of the European build. Thin-lipped and straight-featured, they have straight black hair. The women are many of them very good-looking, somewhat resembling gipsies, but they have rather large hands and feet.'

The men wear a loin-cloth, one end of which is commonly thrown over the shoulder, usually with a knife stuck in the waist, and they invariably carry a stick. The women have the ordinary Arab blue shirt, in most cases kilted at the knees and continued round the waist by a girdle. In some cases, however, they improvise a petticoat of the coarse blankets they themselves weave, and wear on the upper part of the body a loose tunic with short sleeves. They go unveiled. The women wear the hair done up in two plaits which hang down their back, but in front the hair is cut to form a short fringe on the forehead. Their ornaments are few. The men often wear an armlet of silver. The women have necklets of amber, glass beads, dragon's-blood tears, or in some cases rupees, and have also the ordinary Arab silver armlet, and ear-rings.

The occupation of these people is chiefly pastoral. Their herds and flocks are extensive. From the milk they make quantities of ghi by a simple process of churning—merely continuous jerking of the skin mussocks—and they sell it to the Arabs of the coast, or exchange it for rice, dates, or other necessaries. They collect also dragon's-blood and aloes, but the latter only in great amount when pasturage fails them. The women spin a coarse thread from the sheep's wool, which they weave into blankets.

They live very miserably. Milk forms a large portion of their diet. Bombé is used when grown. Rice is obtained from the coast Arabs. Date is a staple of food. On great occasions a sheep or a kid is killed.

The furnishing of their dwellings is very meagre. Blankets are their couches. Goat-skin mussocks are used for water and milk. They have also earthenware pots, moulded by the hand out of the clays and silica of adjacent rocks.

Their language is peculiar. Captain Hunter says of it: 'I could trace no affinity to any of the languages of the neighbouring coasts. It sounds a little like Kis Swahili, but not so soft. It is not Mahri, for the Sultan said it in no way resembled it. The sound is not so guttural as Arabic, and seems to require less effort in enunciation.' Somalis do not understand it. Wellsted says the people of the opposite Arabian coast understand it, but that is not the case. Perhaps Portuguese may have had something to do with it. We made a vocabulary, which increases that of Wellsted, and Captain Hunter, who has considerable knowledge of the tribes in that region, is at present occupied with an investigation into its peculiarities. But I have not heard as yet the result of his studies.

The fact that the Wahabbees visited the island accounts probably for the absence of the many churches, or traces of them, said to exist in ancient times on the island. Wellsted observed some ruins, believed to be of a church. There are, however, still evident the ruined forts of the Portuguese. The largest of these is at Feraigey. No written records have been found; possibly such would disappear along with the churches. Wellsted speaks of inscriptions on the rocks being visible. None of these were seen by us. But on the Kadhab plain there occurs a broad pavement of limestone, 50 yards long by 25 to 30 yards broad, whereon numerous hieroglyphics are cut. The figures are not in line, and do not give the idea of any continuous sentence, and they lie at all angles to one another and varying distances. Some resemble foot-imprints, others distinctly represent a camel, others are like St. Andrew's cross, others are of most irregular form. Of their nature and date I am ignorant, and if any member of the Section, learned in such matters, will aid in deciphering the copies I brought of them I shall be indebted to him.

The government of the island is in the hands of the Sultan of Keshin and Socotra. At present two brothers are joint Sultans, and one lives at Keshin, the other resides in Socotra. They are nephews of the one who, in 1834, refused to sell the island to the British. The Sultan has complete sway in Socotra. He has a residence on Gharriah plain, at the base of the Haggier hills, and has also a palace in Tamarida, where he dispenses justice. Under him each of the large villages has its sheikh or head, and the island is divided into four sections, each of which is in charge of a ranger. The Sultan alone has power to inflict punishment. In each section the land is let out to the various tribes of Bedouins, both for pasture and for the collection of gum, payment therefor being made in ghi. The Sultan only reserves one portion of land for the collection of dragon's-blood for himself.

The trade of the island at present is small, ghi being the chief export. It is carried on by buggalows from the Arabian coast. 'These arrive in the first months of the year with coffee, rice, and other articles, which they exchange for ghi, aloes, orchella weed, &c., which they take to Zanzibar, and, on their return, they bring coco-nut, bombé, and American piece-goods. They dispose of as many of these as possible, and take outward ghi, aloes, dragon's-blood, blankets, &c., and return to Arabia. Pearl-fishers from the Persian Gulf at times visit the island and dispose of their pearls. The Sultan takes tithe of all exports. From ghi his revenue is about 500$, aloes bring him 250$, edah gives 80$, and other sources bring it up to 1,000$ a year, which, with his stipend of 360$ from the British, makes him a comparatively rich man in this region.'

Such, then, is a brief survey of Socotra as it is at the present day.

Many details of interest cannot be included in such a *résumé* as this, but a full account will shortly appear.

It may now be asked, What are the prospects of the island? Is it possible in the future to make anything of it?

There is no doubt but that large tracts of country on the island might, with little difficulty, be brought into a state of cultivation. The hills might be terraced and, by irrigation, water could be taken to spots now dry and parched. The soil is rich, and would support a large crop of cereals, fruits, and vegetables, and with increased pasture the cattle and sheep would multiply enormously. Socotra might thus become a source of supply for the adjacent continents and for passing ships. In addition the aloe-culture might easily be undertaken, and this, with dragon's-blood, boxwood, and orchella weed, would make important articles of commerce. The want of a safe harbour must militate against the commerce of the island, but it is pleasing to be able to say that Luke Thomas & Co., of London and Aden, have fitted out a small steamer, the *Operculum*, which makes her first trip at the end of this month, with the special aim of developing a trade between Socotra and the Arabian and African coasts. One can but wish that it may be the pioneer of a regular trade which will bring the island into contact with civilisation. If dreams of a commercial future for Socotra be considered too sanguine for realisation, it is possible to look to the natural history treasures of the island for valuable contributions to the history of life. After all that has been done we have only a slight knowledge of them. Moreover there is great need for a proper map of the island. The map of Haines and Wellsted (the Admiralty chart) is the only available one, and that is so incomplete and inaccurate regarding the interior, as to be practically useless. Other work during our expedition allowed of no more than mere compass-bearings being taken of the various hills and prominent points, but our data are not sufficient to enable us to make any great change in the map, so that a proper topographical survey is a first necessity.

It was at this Association that Dr. Sclater first brought forward his proposal for an exploration of the island, and it was by funds supplied by this Association that the expedition was at first organised. The results achieved are in great part before the Association, for whom it is to decide whether or no the end has justified the means. If this has been the case, and the results are deemed satisfactory, I would only reiterate that what has been done is but a fragment. Much remains to be done in this region, not only in Socotra itself, but also on the adjacent coasts of Arabia and Africa. Funds only are wanting for the prosecution of the exploration. In conclusion, I will only express the hope that one outcome of this most successful meeting will be the carrying out of the further scientific exploration of these regions.

On some of the Developments of Mechanical Engineering during the last half-century. By Sir FREDERICK BRAMWELL, *V.P. Inst. C.E., F.R.S.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

I AM quite sure the Section will agree with me in thinking—it was very fortunate for us, and for science generally, that our President refrained from occupying the time of the Section by a retrospect, and devoted himself, in that lucid and clear address with which he favoured us, to the consideration of certain scientific matters connected with engineering, and to the foreshadowing of the directions in which he believes it possible that further improvements may be sought for. But I feel it is desirable that some one should give to this Section a record, even although it must be but a brief and an imperfect one, of certain of the improvements that have been made, and of some of the progress that has taken place, during the last fifty years, in the practical application of mechanical science, with which science and its applications our Section is particularly connected. I regret to say that, in common with most of the gentlemen who sat on this platform yesterday—who I think were, without exception, past Presidents of the Section—I am old enough to give this record from personal experience. Fifty years ago I had not the honour of being a member, nor should I, it is true, have been eligible for membership of the Association; for I was at that time vigorously making models of steam-engines, to the great annoyance of the household in which I lived, and was looking forward to the day when I should be old enough to be apprenticed to an engineer.

Without further preface, I will briefly allude to some of the principal developments of a few of the branches of engineering. I am well aware that many branches must necessarily be left unnoticed; but I trust that the omissions I may make will be remedied by those present who may speak upon the subject after me.

I will begin by alluding to the *Steam Engine employed for manufacturing purposes.* In 1831 the steam-engine for these purposes was commonly the condensing beam-engine, and was supplied with steam from boilers known, from their shape, as waggon-boilers. This shape appears to have been chosen rather for the convenience of the sweeps, who periodically went through the flues to remove the soot consequent on the imperfect combustion, than for the purpose of withstanding the internal pressure of steam. The necessary consequence was, that the manufacturing engines of those days were compelled to work with steam of from only 3½ lbs. to 5 lbs. per square inch of pressure above atmosphere. The piston-speed rarely exceeded 250 feet per minute, and as a result of the feeble pressure and of the low rate of speed, very large cylinders indeed were needed relatively to the power obtained. The consumption of fuel was heavy, being commonly from 7 lbs to 10 lbs. per gross indicated horse-power per hour. The governing of the engine was done by pendulum-governors, revolving slowly, and not calculated to exert any greater effort than that of raising the balls at the end of the pendulum-arms, thus being, as will readily be seen, very inefficient regulators. The connection of the parts of the engine between themselves was derived from the foundation upon which the engine was supported. Incident to the low piston-speed was slowness of revolution, rendering necessary heavy fly-wheels to obtain even an approach to practical uniformity of rotation, and frequently rendering necessary also heavy trains of toothed gearing to bring up the speed from that of the revolution of the engine to that of the machinery it was intended to drive.

In 1881 the boilers are almost invariably cylindrical, and are very commonly fired internally, either by one flue or by two; and we owe it to the late Sir William Fairbairn, President of the British Association in 1861, that the danger which at one time existed of the collapse of these fire-flues has been entirely removed, by his application of circumferential bands. Now-a-days there are, as we know, modifications of Sir William Fairbairn's bands; but by means of his bands, or by modifications thereof, all internally flued boilers are so strengthened that the risk of a collapse of the flue is at an end. Boilers of this kind are well calculated to furnish, and commonly do furnish, steam of from 40 lbs. to 80 lbs. pressure above atmosphere; the piston-speed is now very generally 400 feet or more, so that, notwithstanding that there is usually a liberal expansion, the mean pressure upon the piston is greater, and this, coupled with the increased piston-speed, enables much more power to be obtained from a given size of cylinder than was formerly obtainable. The revolutions of the engine now are as many as from 60 to 200 per minute, and thus, with far lighter fly-wheels, uniformity of rotation is much more nearly attained. Moreover, engines are now self-contained, and no longer depend upon the foundation for the connection of their parts. In many cases the condensing is effected either by surface condensers, or, where there is not an ample supply of water, the condensation is in a few instances effected by the evaporative condenser—a condenser which, I am sorry to say, is not generally known, and is therefore but seldom used, although between thirty and forty years have elapsed since its first introduction. Notwithstanding the length of time during which the evaporative condenser has been known to some engineers, it is a common thing to hear persons say, when you ask them if they are using a condensing engine, 'I cannot use it, I have not water enough'—a very sufficient answer, indeed, if an injection condenser or an ordinary surface condenser constituted the sole means by which a vacuous condition might be obtained, but a very insufficient answer having regard to the existence of the evaporative condenser, as by its means whenever there is water enough for the feed of a non-condensing engine, there is enough to condense the exhaust steam, and to produce a good vacuum. The evaporative condenser simply consists of a series of pipes, in which is the steam to be condensed, and over which the water is allowed to fall in a continuous rain. By this arrangement there is evaporated, from the outside of the condenser, a weight of water, which goes away in a cloud of vapour and is nearly equal to the weight of steam which is condensed, and is returned as feed water into the boiler. The same water is pumped up and used outside the condenser over and over again, needing no more to supply the waste than would be needed as feed water, and as the condenser acts by evaporation its effect is practically as good whether the external water be warm or cold. Although this condenser has, as I have said, been in use for thirty or forty years, there are still to be seen engines, working without condensation at all, or with waterworks water, purchased at a great cost, and to the detriment of other consumers who want it for ordinary domestic purposes; or large condensing ponds are used in which the injection water is stored, to be worked over and over again, and frequently (especially towards the end of the week) in so tepid a state as to be unfit for its purpose. The governing is now done by means of quick-running governors, which have power enough in them to raise, not merely the pendulum-balls, which are small, but a very heavy weight, and in this way the governor is extremely effective. I propose to say no more —looking at the magnitude of the whole of my subject—upon the engine used for manufacturing purposes, but rather to turn at once to those employed for other objects.

Steam Navigation.—In 1831 there were a considerable number of paddle-steamers running on some of the rivers in England and across the Channel to the Continent. But there were no ocean steamers, properly so called, and there were no steamers used for warlike purposes. As in the case of the waggon-boilers, the boilers of the paddle-steamers of 1831 were most unsuited for resisting pressure. They were mere tanks, and as tanks the downward strain from the mere weight of water was as great on the bottom plates, even in the absence of any steam-pressure within the boiler at all, as, when the steam was up, was the upward strain on the top plates. Under these circumstances, again, from $3\frac{1}{2}$ lbs. to 5 lbs. on the square inch was all the pressure the boilers were competent to bear, and this feeble pressure, coupled with the slow speed at which the engines ran, caused them to develop but a small amount of horse-power in relation to their size. Moreover, as in the land engine, the connection between the parts of the marine engine was such as to be incompetent to stand the strain that would come upon it if a higher pressure, with a considerable expansion, were used, and thus the consumption of coal was very heavy; and we know, that having regard to the then consumption, it was said, on high authority, it would be impossible for a steam-boat to cross the Atlantic, as it could not carry fuel enough to last out the voyage; and it was not till 1838 that the *Sirius* and the *Great Western* did make the passage. One boat, it is true, had crossed before, but it was not till 1838 that passenger traffic was really commenced. In 1831, owing to the condensation being effected by injection, the marine boiler was supplied with salt water, the hulls were invariably of wood, and the speed was, probably, from eight to nine knots an hour. In 1881 the vessels are as invariably either of iron or of steel, and I believe it will not be very long before the iron disappears, giving place entirely to the last-mentioned metal. With respect to the term 'steel' I am ready to agree that it is impossible to say where, chemically speaking, iron ends and steel begins. But (leaving out malleable cast-iron) I apply this term steel to any malleable ductile metal of which iron forms the principal element, and which has been in fusion, and I do so in contradistinction to the metal which may be similar chemically but which has been prepared by the puddling process. Applying the term steel in that sense, I believe, as I have said, it will not be very long before plate iron, produced by the puddling process, will cease to be used for the purpose of building vessels. With respect to marine engines these are now supplied with steam from multiple-tubed boilers which are commonly cylindrical. They are of enormous strength and made with every possible care, and carry from 80 to 100 lbs. pressure on the square inch. It has been found, on the whole, more convenient to expand the steam in two or more cylinders rather than in one. I quite agree that, as a mere matter of engineering science, there is no reason why the expansion should not take place in a single cylinder, unless it be that you cool down a single cylinder to an extent which cannot be overcome by jacketing, and which, therefore, destroys a portion of the steam on its entrance into the cylinder. As regards the propeller, as we know, except in certain cases, the paddle-wheel has practically disappeared, and we have the screw-propeller employed, either singly, or in pairs. This substitution of the screw-propeller for the paddle enables the engines to work at a much greater number of revolutions per minute, and thus a piston-speed of some 600 to 800 feet per minute is attained; and this, coupled with the fairly high mean pressure which prevails, enables a large power to be got from a comparatively small-sized engine. Speeds of 15 knots an hour are now in many cases maintained by steam-vessels throughout their voyages, and on trial trips are not uncommonly exceeded. The steam-vessel is now the accepted vessel of war. We have them in an armoured state and in an unarmoured state, but when unarmoured rendered so formidable by the power which their speed gives them of choosing their distance, as to make them, when furnished with powerful guns, dangerous opponents even to the best armoured vessels. We have also now marine engines governed by governors of such extreme sensitiveness as to give them the semblance of being endowed with the spirit of prophecy, as they appear rather to be regulating the engine for that which is about to take place than for that which is taking place. This may sound a somewhat extravagant statement, but it is so nearly the truth that I have hardly gone outside of it, in using the words I have employed. For a marine governor to be of any use it must not wait till the stern of the vessel is out of the water, before it acts to check the engine and reduce the speed; nothing but the most sensitive and indeed anticipatory action of the governor can efficiently control marine propulsion. Instances are on record of vessels having engines without marine governors, being detained by stress of weather at the mouth of the Thames, while vessels having such governors, of good design, have gone to Newcastle, have come back, and have found the other vessels still waiting for more favourable weather. With respect to condensation in marine engines it is almost invariably effected by surface-condensers, and thus it is that the boilers, instead of being fed with salt water as they used to be, involving continuous blowing-off and frequently the salting-up of the boiler, are now fed with distilled water. It should be noticed, however, that in some instances, owing to the absence of a thin protecting scale upon the tubes and plates, very considerable corrosion has taken place, especially where distilled water, derived from condensers having un-tinned brass tubes, has been used for the feed, and where the water has carried into the boiler fat-acids arising from the decomposition of the grease used in the engine; means are now employed by which these effects are counteracted.

I wish before quitting this section of my subject, to call your attention to two very interesting but very differing kinds of marine engines. One is the high-speed torpedo-vessel or steam launch of which Messrs. Thornycroft have furnished so many examples. In these, owing to the rate at which the piston runs, to the initial pressure (120 lbs.), and to very great skill in the design, Messrs. Thornycroft have succeeded in obtaining a gross indicated horse-power for as small a weight as half a cwt., including the boiler, the water in the boiler, the engine, the propeller shaft, and the propeller itself. To obtain the needed steam from the small and light boiler, recourse has to be made to a fan-blast driving air into a closed stoke-hold. From the use of a blast in this way two excellent things happen: one is, as already stated, that from a small boiler a very large amount of steam is produced, and the other that the artificial blast, when thus applied, is unaccompanied by the dangers which arise when, under ordinary circumstances, the blast is applied only to the ash-pit itself. The other marine engine to which I wish to call your attention, is one that has been made with a view to great economy. The principles followed in its construction are among those suggested by the President (Sir W. G. Armstrong) in his address. He—you will remember—pointed out that the direction in which economy in the steam-engine was to be looked for was in that of increasing the initial pressure; although, at the same time, he said, there were drawbacks, in the shape of greater loss by radiation, and by the higher temperature at which the products of combustion would escape. We must admit the fact of the latter source of loss when using a very high pressure of steam, it being inevitable that the temperature of the products of combustion escaping from a boiler under these conditions must be higher than those which need be allowed to escape when a lower pressure of steam is employed; although I regret to say that in practice in marine boilers, working at comparatively low pressures, the products are ordinarily suffered to pass into the funnel, at above the temperature of melting lead.[1] But with respect to the loss by radiation in the particular engine I am about to mention—that of Perkins—there is not so much loss as that which prevails in the ordinary marine boiler, because the Perkins boiler is completely enclosed, with the result that while there is within the case a boiler containing steam of 400 lbs. on the square inch, and the fire to generate that steam, the hand may be applied to the casing itself, which contains the whole of the boiler, without receiving any unpleasant sensation of warmth. By Mr. Perkins' arrangement, using steam of 400 lbs. in the boiler, it was found, as the result of very severe trials conducted by Mr. Rich, of Messrs. Easton and Anderson's firm, and myself—trials which lasted for twelve hours—that the total consumption of fuel, including that for getting up steam from cold water, was just under 1·8 (actually 1·79) lbs. per gross indicated horse-power per hour. That consumption was ascertained in a manner which it is desirable should always be employed in steam-boat trials. It was not arrived at by using as a divisor the horse-power of the most favourable diagram obtained during the day, but it was got from diagrams taken every half-hour during the regular work; then, when the pressure began to die down, from coal being no longer put upon the fire, diagrams taken every quarter of an hour; and then, towards the last, every five minutes; and the total number of foot-pounds were calculated from these diagrams, and were used to obtain the gross indicated horse-power.

Further, so far as could be ascertained by the process of commencing a trial with a known fire, and closing that trial, at the end of six hours, with the fire as nearly as possible in the same condition, the consumption was 1·66 lbs. of coal per gross indicated horse-power per hour, so that, without taking into account the coal consumed in raising steam from cold water, the engine worked for $1\frac{2}{3}$ lbs. of coal per horse per hour. I think it well to give these details because, undoubtedly, this is an extremely economical result.

Our President alluded to the employment of ether as a means of utilising the heat which ordinarily escapes uselessly into the condenser,

[1] It should have been noticed, that although the products of combustion must escape from the boiler at a greater temperature where a high pressure of steam is employed than they *need* escape at where a lower pressure is used, it does not follow that loss should accrue on this account, as the excess can, by means of a heater, be taken up by the feed water: a plan Mr. Perkins is employing in practice.

and he gave some account of that which was done by M. Du Tremblay in this direction. It so happened I had occasion to investigate the matter at the time of Du Tremblay's experiments. Very little was effected here in England, one difficulty being the excise interference with the manufacture of ether. Chloroform was used here, and it was also suggested to employ bi-sulphide of carbon. In France, however, a great deal was done. Four large vessels were fitted with the ether-engine, and I went over to Marseilles to see them at work. I took diagrams from them, and found that by this system the exhaust steam from the steam-cylinder, which was condensed by the application of ether to the surface of the steam-condenser (producing a respectable vacuum of 22 inches), gave an ether-pressure of some 15lbs. on the square inch above atmosphere, and that very economical results as regards fuel were obtained. The system was, however, eventually abandoned, owing to practical difficulties. It need hardly be said that ether-vapour is very difficult to deal with, and although ether is light the vapour is extremely heavy, and if there is any leak in the apparatus the vapour goes down into the bilges by gravitation, and being mixed with air, unless due care is taken to prevent access to the fires, there would be a constant risk of a violent explosion. In fact, it was necessary to treat the engine-room in the way in which a fiery colliery would be treated; the light, for instance, was by lamps external to the engine-room, and shining through thick plate glass, while the hand-lamps were Davy's. The Ether Engine was a bold experiment in applied science, and one that entitles Du Tremblay's name to be preserved and to be mentioned as it was by our President. There was another kind of marine engine that I think should not be passed over without notice. I allude to Howard's Quicksilver Engine. The experiments with this engine were persevered in for some considerable time, and it was actually used for practical purposes in propelling a passenger vessel called the *Vesta*, running from London to Ramsgate. In that engine the boiler had a double bottom containing an amalgam of quicksilver and lead. This amalgam served as a reservoir of heat, which it took up from the fire below the double bottom, and gave forth at intervals to the water above it. There was no water in the boiler, in the ordinary sense of the term, but when steam was wanted to start the engine, a small quantity of water was injected by means of a hand pump, and after the engine was started there was pumped by it into the boiler, at each half-revolution, as much water as would produce the steam needed. This water was dispersed on the top surface of the reservoir in which the amalgam was confined, and was entirely flashed into steam, the object of the engineer in charge being to send in only so much as would just generate the steam, without leaving any water in the boiler. The engines of the *Vesta* were made by Mr. Penn for Mr. Howard, of the King and Queen Ironworks, Rotherhithe. Mr. Howard was, I fear, a considerable loser by his meritorious efforts to improve the steam-engine.

The President: What sort of results did they get in point of economy?

Sir Frederick Bramwell: I don't know, but I believe they got moderately good results. There was used with this engine an almost unknown mode of obtaining fresh water for the boiler. Fresh water, it will be seen, was a necessity in this mode of evaporation, as the presence of salt or any other impurity when the whole of the water was flashed into steam, must have caused a deposit at the top of the amalgam chamber at each operation. Fresh water, therefore, was needed, and the problem then arose how to get it; and that problem was solved, not by the use of surface-condensation, but by the employment of re-injection; that is to say, an ordinary injection-condenser being used, the water delivered from the hot well was passed into pipes external to the vessel; after traversing them it came back into the injection-tank sufficiently cooled to be used again. The boilers were worked by coke fires urged by a fan-blast in their ashpits, but I am not aware that this mode of firing was a needful part of the system.

Engines used for Railways.—At the British Association Meeting of 1831 the Manchester and Liverpool Railway had been opened only about a year. The Stockton and Darlington coal-line, it is true, had carried passengers by steam-power as early as 1825; but I think we may look upon the Manchester and Liverpool as being the beginning of the passenger and mercantile railway system of the present day. In 1831 the locomotives weighed from eight to ten tons, and the speed was about twenty miles per hour, with a pressure of steam in the boiler of from 40 to 50 lbs. The rails were light, they were jointed in the chairs, which were generally carried on stone blocks, thus affording most excellent anvils for the battering to pieces of the ends of the rails, that is to say, for the destruction of the very parts where they were most vulnerable. The engines were not competent to draw heavy trains, and it was a common practice to have at the foot of an incline a shed containing a 'bank engine,' which ran out after the trains as they passed, and pushed them up to the top of the hill. Injectors were then unknown, and donkey-pumps were unknown, and therefore, when it was necessary to fill up the boiler, if it had not been properly pumped up before the locomotive came to rest, then the locomotive had to run about the line in order to work its feed-pumps. To get over this difficulty, it was occasionally the practice to insert into a line of rails, in a siding, a pair of wheels, with their tops level with those of the rails, so that the engine wheels could run upon their rims. Then, the locomotive being fixed, to prevent it from moving off the pair of wheels endways, it was put into revolution, its driving wheels bearing, as already stated, upon the rims of the pair of wheels in the rails, and thus the engine worked its feed-pumps, without interfering (by its needless running up and down the line) with the traffic. It should have been stated that at this time there was no link motion, no practical expansion of the steam, and that even the reversal of the engine had to be effected by working the slides by hand gear, in the manner in use in marine engines. When the British Association originated, although the Manchester and Liverpool Railway had been opened for a year, there is no doubt that the 300 members who then came to this city, found their way here by the slow process of the stage coach, the loss of which we so much deplore in the summer and in fine weather, but the obligatory use of which we should so much regret in the miserable weather now prevailing in these islands. In 1881 we know that railways are everywhere. Steel rails, double the weight of the original iron ones, are used. Wooden sleepers have replaced the stone blocks, and they in their turn will probably give way to sleepers of steel. The joints are now made by means of fishplates, and the most vulnerable part of the rail, the end, is no longer laid on an anvil for the purpose of being smashed to pieces, but the ends of the rails are now almost always over a void, and thereby are not more affected by wear than is any other part of the rail. The speed is now from 50 to 60 miles an hour for passenger trains, while slow-speed goods engines, weighing 45 tons, draw behind them coal trains of 800 tons. The injector is commonly employed, and by its aid a careful driver of the engine of a stopping train can almost succeed in doing the whole of the feeding at the time when his engine is at rest at the stations, and when, therefore, no demand is being made on the boiler. The link motion is in common use, to which, no doubt, is owing the very considerable economy with which the locomotive engine now works. As regards the question of safety, it is a fact, that, notwithstanding the increased speed, railway accidents are fewer in proportion than they were at the slow speed. Indeed, the number of deaths is so small that, if the whole population of London were to take a railway journey, there would be but one death arising out of it. Four millions of journeys for one death of a passenger from causes beyond his own control, is, I believe, a state of security which rarely prevails elsewhere than in a railway train. As an instance, the street accidents in London alone cause between 200 and 300 deaths per annum. This safety in railway-travelling is, no doubt, largely due to the block system, rendered possible by the electric telegraph; and also to the efficient interlocking of points and signals, which makes it impossible now for a signalman to give an unsafe signal. He may give an incorrect one, in the sense of inviting the wrong train to come in, but although incorrect in this sense, it would still be safe for that train to obey it. If he can give a signal that signal never invites to danger. Before he can give it every one of the signals which ought to be at danger must be at danger, and every point must have been previously set so as to make the road right. Then again, we have the facing-point-lock, which is a great source of safety. Further, we have continuous brakes of various kinds, competent in practice to absorb three miles of speed in every second of time—that is to say, if a train were going 60 miles an hour it can be pulled up in 20 seconds, or if at the rate of 30 miles in 10 seconds. With a train running at 50 miles an hour it can be pulled up in from 15 to 20 seconds, and in a distance of from 180 to 240 yards. Moreover, in the event of the train separating into two or more sections, the brakes are automatically applied to all the sections, thereby bringing them to rest in a short time. Another cause of safety is undoubtedly the use of weldless tyres. I was fortunate enough to attend the British Association Meeting many years ago at Birmingham, and I then read a paper upon weldless tyres, in which I ventured to prophesy that in ten years' time there would not be a welded tyre made. That is one of the few prophecies that, being made before the event, have been fulfilled. I may perhaps be permitted to mention that at the same time I laid before Section G plans and suggestions for the making of the cylindrical parts of boilers also without seam or even welding. This is rarely done at the present time, but I am sure that in twenty years' time such a thing as a longitudinal seam of rivets in a boiler will be unknown. There is no reason why the successive rings of boiler-shells should not be made weldless, as tyres are now made weldless.

The next subject I intend to deal with is that of *Motors*. In 1831 we had the steam-engine, the water-wheel, the windmill, horse power, manual power, and Stirling's hot-air engines. Gas engines, indeed, were proposed in 1824, but were not brought to the really practical stage. We had then tide-mills; indeed we have had them until quite lately, and it may be that some still exist. They were sources of economy in our fuel, and their abandonment is to me a matter of regret. I remember tide-mills on the coast between Brighton and Newhaven; another between Greenwich and Woolwich, another at Northfleet, and others in various places. Indeed such mills were used pretty extensively. They were generally erected at the mouth of a stream, and in that way the river-bed made the reservoir, and even when they were erected in other situations those were of a kind suitable for the purpose—that is, low-lying lands were selected and were embanked to form reservoirs. In 1881 wind-mills and water-wheels are much the same as they were in 1831; but turbines are greatly improved, and by means of the turbine we are enabled to make available the pressure derived from heads of water which formerly could not be used at all, or if used they involved the erection of enormous water-wheels, such as those at Glasgow and in the Isle of Man, wheels of some 80 feet in diameter. But now by means of a small turbine an excellent effect is produced from high heads of water. The same effect is obtained from the water-engines which our President has employed with such great success. In addition to these motors we have the gas-engine, which within the last few years only has become a really useful working and economical machine. With respect to horse-power motors we have not only the old horse-machines, but we have a new application (as it seems to me) of the work of the horse as a motor. I allude to those cases where the horse, drawing a reaping or thrashing machine, not only pulls it forward as he might pull a cart, but causes its machinery to revolve so as to perform the desired kind of work. This species of horse-engine, though known, was but little used in 1831. With respect to hot-air engines there have been many attempts to improve them, and some hot-air engines are working, and with considerable success; but the amount of power they develop in relation to their size is small, and I am inclined to doubt whether it can be much increased.

I now come to the subject of the *Transmission of Power*. I do not mean transmission in the ordinary sense by means of shafting, gearing, or belting, but I mean transmission over long distances. In 1831 we had for this purpose flat rods, as they were called—rods transmitting power from pumping engines for a considerable distance to the pits where the pumps were placed, and we had also the pneumatic, the exhaustion system, the invention of John Hague, a Yorkshireman, my old master, to whom I was apprenticed, which mode of transmission was then used to a very considerable extent. The recollection of it, I find, however, has nearly died out, and I am glad to have this opportunity of reviving it. But in 1881 we have for the transmission of power, first of all quick-moving ropes, and let me refer you to an excellent instance of this system at Schäffhausen. Anyone who has in recent years gone a mile or two above the falls at Schäffhausen must have seen there, in a house on the bank of the Rhine, opposite to that on which the town is situated, large turbines driven by the river, which is slightly dammed for the purpose. These work quick-going ropes carried on pulleys, erected at intervals along the river-bank for the whole length of the town, and power is delivered from them to shafting below the streets, and from it into any house where it is required for manufacturing purposes. Then we have the compressed-air transmission of power, a mode which is very largely used for underground engines, and for the working of rock-drills in mines and tunnels. We have also compressed air in a portable form, and it is now employed with great success in driving tramcars. I had occasion last January to visit Nantes, where for eighteen months tramcars had been driven by compressed air, carried on the cars themselves, coupled with an extremely ingenious arrangement for overcoming the difficulties commonly attendant on the use of compressed-air engines. This consists in the provision of a cylindrical vessel half filled with hot water and half with steam at a pressure of 80 lbs. on the square inch; the compressed air on its way from the reservoir to the engine passes through the water and steam, becoming thereby heated and moistened, and thus all the danger of forming ice in the cylinders is prevented and the pistons and slides are susceptible of good lubrication. These cars, which start every ten minutes from each end, make a journey of $3\frac{3}{4}$ miles, and have proved to be a commercial and an engineering success. I believe, moreover, that the system is capable of very considerable improvement. Then there is, although not much used, the transmitting of power by means of long steam pipes. There is also the transmission hydraulically. This may be carried out in an intermittent manner, so as to replace the reciprocating flat rods of old days. That is to say, if two pipes containing water are laid down, and if the pressure in those pipes at the one end be alternated, there will be produced an alternating and a reciprocative effect at the other end, which may be employed to give motion to pumps or other machinery. There is also that thoroughly well-known mode of transmission hydraulically for which the engineering world owes so much to our President. We have, by Sir William Armstrong's system, coupled with his accumulator, the means of transmitting hydraulically the power of a central motor to any place requiring it, and by means of the principal accumulator, or if need be by that aided by local accumulators, a comparatively small engine is enabled to meet very heavy demands made upon it for a short time. I think I am right in saying that at the ordinary pressure which Sir William Armstrong uses in practice, viz., 700 lbs. to the square inch, one foot per second of motion along an inch pipe would deliver at the rate to produce one horse-power. Therefore a 10-inch pipe with the water travelling at no greater pace than 3 feet in a second would deliver 300 horse-power. This 300 horse-power would, no doubt, be somewhat reduced by the loss in the hydraulic engine, which would utilise the water, but the total energy received would be equivalent to producing 300 horse-power. Such a transmission would be effected with an exceedingly small loss in friction in transit; I believe I am right in saying, that a 10-inch pipe a mile long would not involve much more than about 14 lbs. or 15 lbs. differential pressure to propel the water through it at a rate of 3 feet in a second. If that be so, then with 700 lbs. to the inch, the loss under such circumstances would be only 2 per cent. in transmission. There is no doubt that this transmission of power hydraulically has been of the greatest possible use. It has enabled work to be done which could not be done before. Enormous weights are raised with facility wherever required, as, by the aid of power hydraulically transmitted, it is perfectly easy for one man to manage the heaviest crane. Moreover, as I have said in other places, this system, which we owe to Sir William Armstrong, has gone far to elevate the human race, and it has done so in this manner. So long as it is competent for a man to earn a living by a mere unintelligent exercise of his muscles he is very likely so to do. You may see in the old London Docks the crane-heads covered by structures that look like paddle-boxes; if you go up to them you will find, I am glad to say, there is nothing now to occupy them; but at the date when the British Association first met, these paddle-boxes covered large tread-wheels, in which the men trod so as to raise a weight. Now, although I know that, in fact, there is nothing more objectionable in a man turning a wheel by treading inside of it, than there is if he turn it round by a winch-handle, yet somehow it strikes one more as being merely the work of an animal, a turnspit or a squirrel, or indeed as being the task imposed on the criminal. Nevertheless, in this way there were a large number of persons getting their living by the mere exercise of their muscles, but, as might be expected, a very poor living, derived as it was from unintelligent labour. That work, since the introduction of Sir William's hydraulic system, is no longer possible, and is not so for the powerful reason that it does not pay. Those persons, therefore, who would formerly have been thus occupied are compelled to elevate themselves, and to become competent to earn their living in a manner which is more worthy of an intelligent human being. It is on these grounds that I say we owe very much the elevation of the working classes—especially of the class below the artizan—to this excellent invention of our distinguished President.

In addition to the modes of transmission I have already mentioned, there is the *Transmission of Power by means of Gas.* I think that there is a very large future indeed for gas-engines. I do not know whether this may be the place wherein to state it, but I believe the way in which we shall utilise our fuel hereafter will, in all probability, not be by the way of the steam-engine. Sir William Armstrong alluded to this probability in his address, and I entirely agree—if he will allow me to say so—that such a change in the production of power from fuel appears to be impending, if not in the immediate future, at all events in a time not very far remote: and however much the Mechanical Section of the British Association may to-day contemplate with regret even the mere distant prospect of the steam-engine becoming a thing of the past, I very much doubt whether those who meet here fifty years hence will then speak of that motor except in the character of a curiosity to be found in a museum.

With respect to the transmission of power electrically I won't venture to touch upon that; but will content myself by reminding you that, while Sir William Armstrong did refer to the fact that there were comparatively small streams which could be utilised, he did not inform you of what he himself had done in this direction. Let me now say that Sir William Armstrong has thus utilised a fall of water situated about a mile from his house, to work a turbine, which drives a dynamo-machine generating electricity for the illumination of the house. When I was last at Crag Side that illumination was being effected by the arc light, but since then, he has replaced the arc light by the incandescent lamp (a form of electrical lighting far more applicable than the arc light to domestic purposes), and has done this with the greatest possible success. Thus in Sir William Armstrong's own case a small stream is made to afford light in a dwelling a mile away. Certainly nothing could have seemed more improbable fifty years ago than that the light of a house should be derived from a fall of water without the employment of any kind or description of combustible matter.

The next subject upon which I propose to touch is that of the *Manufacture of Iron and Steel.* In 1831, Neilson's hot blast specification had been published for $2\frac{1}{2}$ years only. The Butterley Company had tried the hot blast for the first time in the November preceding the meeting of the British Association; the heating of the blast was coming very slowly into use, and the temperature attained when heating was employed was only some 600 degrees. The ordinary blast furnace of those days was 35 to 40 feet high, and about 12 feet diameter at the boshes, and turned out about 60 tons a week. It used about $2\frac{1}{2}$ tons of coal per ton of iron, and no attempt was made to utilise the waste gases, whether escaping in the form of gas or in the form of flame, the country being illuminated for miles around at night by these fires. The furnaces were also open at the hearth, and continuous fire poured out along with the slag. In 1881 blast furnaces are from 90 to 100 feet high and 25 feet in diameter at the boshes; and they turn out from 500 to 800 tons a week. The tops and also the hearths are closed, and the blast, thanks to the use of Mr. E. A. Cowper's stoves, is at 1,200 degrees. The manufacture of iron has also now enlisted in its service the chemist as well as the engineer, and amongst those who have done much for the improvement of the blast furnace, to no one is greater praise due than to Mr. Isaac Lowthian Bell, who has brought the manufacture of iron to the position of a highly scientific operation. In the production of wrought iron by the puddling process, and in the subsequent mill operations, there is no very considerable change except in the magnitude of the machines employed and in the greater rapidity with which they now run. In saying this I am not forgetting the various mechanical puddlers which have been put to work, nor the attempts which have been made by the use of some of them to make wrought-iron direct from the ore; but neither the mechanical puddler nor the direct processes have yet come into general use, and I desire to be taken as speaking of that which is the ordinary method pursued at the present in puddled iron manufacture. In 1831 a few hundredweights was the limit of weight of a plate, while in 1881 there may readily be obtained for boiler-making purposes plates of at least four times the weight of those that were the limit of weight in 1831. I may, perhaps, be allowed to say that there is an extremely interesting Blue Book of the year 1818, containing the report of a Parliamentary Committee which was appointed to investigate a boiler explosion, and I recommend any mechanical engineer who is interested in the history of the subject to read that book. He will find it there stated that in the North of England there was a species of engines called locomotives, the boilers of which were made of wrought-iron beaten, not rolled, because the rolled plate was not considered fit; it was added that if made of beaten iron the boiler would last at least a year.

In 1831, thirteen years later, the dimensions of rolled plates were, no doubt, raised; but few then would have supposed it possible there should be rolled such plates as are now produced for boiler purposes, and still fewer would have believed that in the year 1881 we should make for warlike purposes rolled plates 22 inches in thickness and 30 tons in weight. I have said there is very little alteration in the process of making wrought iron by puddling, and I do not think there is likely to be much further, if any, improvement in this process, because I believe that, with certain exceptions, the manufacture of iron by puddling is a doomed industry. I ventured to say, in a lecture I delivered at the Royal Institution three years ago, on 'The Future of Steel,' that I believed puddled iron, except for the mere hand-wrought forge purposes of the country blacksmith, and for such-like purposes, would soon become a thing of the past. Mr. Harrison, the engineer of the North Eastern Railway, told me that about eighteen months ago that railway applied for tenders for rails in any quantities between 2,000 and 10,000 tons, and issued alternative specifications for iron and for steel. They received about ten tenders; certain of those who sent them in did not care to tender for iron at all, and in some cases where the alternative price was quoted, that for the iron exceeded that for the steel. I have no doubt whatever that in a short time it will be practically impossible to procure iron, made by the puddling process, of dimensions fit for many of the purposes for which a few years ago it alone was used. With respect to steel, in 1831 the process in use was that of cementation, producing blistered steel, which was either piled and welded to make shear steel, or was broken into small pieces, and melted in pots, and run into ingots weighing only some 50 lbs. or 60 lbs. each. At that time steel was dealt in by the pound; nobody thought of steel in tons. In 1881 we are all aware that by Sir Henry Bessemer's well-known discovery, carried out by him with such persistent vigour, cast-iron is by the blowing process converted into steel; and that by Dr. Siemens' equally well-known process, now that, owing to his invention of the regenerative furnace, it is possible to obtain the necessary high temperature, steel is made upon the open hearth; and we are moreover aware that by both of these processes it is produced in quantities of many tons at a single operation, with the result that, as instanced in the case of the North Eastern rails, steel is a cheaper material than the wrought-iron made by the puddling process. One cannot pass away from the steel manufacture without alluding to Sir Joseph Whitworth's process of putting a pressure on the steel while in a fluid state. By this means the cavities which are frequently to be found in ingots of a large size, are, while the material is still fluid, considerably diminished, and the steel is thereby rendered much more sound. In conclusion of my observations on the subject of iron and steel manufacture, I wish to call attention to the invention of Messrs. Thomas & Gilchrist, by which ores of iron containing impurities that unfitted them to be used in the manufacture of steel, are now freed from these impurities, and are thus brought into use for steel-making purposes.

With respect to *Bridges*: in the year 1831 bridges of cast-iron existed, but no attempt had been made to employ wrought-iron in girder bridges, although Telford and others had employed it in suspension bridges; but in 1881 the introduction of railways and the improvements in iron manufacture have demanded and have rendered possible the execution of such bridges as the tubular one stretching across the Menai Straits in spans of 400 feet, and the Saltash over the Tamar, with spans of 435 feet; while the recent great improvements in the manufacture of steel have rendered possible the construction of the contemplated Forth Bridge, where there are to be spans of 1,700 feet, or one-third of a mile in length. Mr. Barlow (one of the engineers of this bridge) has told me that there will be used upwards of 2,000 more tons in the Forth Bridge to resist the wind-pressure, than would have been needed if no wind had had to be taken into account, and if the question of the simple weight to be carried had alone to be considered. With respect to the foundation of bridges, that ingenious man, Lord Cochrane, patented a mode of sinking foundations even before the first meeting of the British Association—viz., as far back, I believe, as 1825 or 1826; and the improvements which he then invented are almost universally in use in bridge-construction at the present day. Cylinders sunk by the aid of compressed air, 'air-locks' to obtain access to the cylinders, and, in fact, every means that I know as having been used in the modern sinking of cylinder foundations, were described by Lord Cochrane (afterwards Earl of Dundonald) in that specification.

The next subject I propose to touch upon is that of *Machine Tools.* The mention of lathes, drilling machines, and screwing machines brings me very nearly to the end of the list of the machine tools used by turners and fitters in 1831, and at that time many of the lathes were without slide-rests. The boiler-maker had then his punching press and shearing-machine; the smith, leaving on one side his forges and the bellows, had nothing but hand tools, and the limit of these was a huge hammer with two handles, requiring two men to work it. In anchor manufacture, it is true, a mechanical drop-hammer, known as a Hercules, was employed; while in ironworks the Helve and the Tilt hammer were in use. For ordinary smith's-work, however, there were, as has been said, practically no machine tools at all.

This paucity, or indeed, absence in some trades, as we have seen, of machine tools, involved the need of very considerable skill on the part of the workman. It required the smith to be a man not only of great muscular power, but to be possessed of an accurate eye and a correct judgment, in order to produce the forgings which were demanded of him, and to make the sound work that was needed, especially when that soundness was required in shafts and in other pieces which in those days were looked upon as of magnitude, as, indeed, they were relatively to the tools which could be brought to operate upon them. The boiler-maker in his work had to trust almost entirely to the eye for correctness of form and for regularity of punching, while all parts of engines and machines which could not be dealt with in the lathe, in the drilling, or in the screwing machine, had to be prepared by the use of the chisel and the file.

At the present day the turning and fitting shops are furnished not only with the slide-lathe, self-acting in both directions, and screw-cutting, the drilling machine, and the screwing machine, but with planing machines competent to plane horizontally, vertically, or at an angle; shaping machines, rapidly reciprocating and dealing with almost any form of work; nut-shaping machines; slot-drilling machines, and slotting machines; while the drills have become multiple and radial, and the accuracy of the work is ensured by testing on large surface-plates, and by the employment of Whitworth internal and external standard gauges.

The boiler-maker's tools now comprise the steam, compressed air, hydraulic, or other mechanical riveter; rolls for the bending of plates, while cold, into the needed cylindrical or conical forms; multiple drills for the drilling of rivet-holes; planing machines to plane the edges of the plates; ingenious apparatus for flanging them, thereby dispensing with one row of rivets out of two; and roller-expanders for expanding the tubes in locomotive and in marine boilers; while the punching press, where still used, is improved so as to make the holes for seams of rivets in a perfect line and with absolute accuracy of pitch.

With respect to the smith's shop, all large pieces of work are now manipulated under heavy Nasmyth or other steam-hammers; while smaller pieces of work are commonly prepared either in forging machines or under rapidly-moving hammers, and when needed in sufficient numbers, are made in dies; and applicable to all the three industries of the fitting shop, the boiler shop, and the smith's shop, and also to that other industry carried on in the foundry, are the travelling and swing cranes, commonly worked by shafting or by quick-moving ropes for the travellers, and by hydraulic power or by steam-engines for the swing cranes. It may safely be said that without the aid of these implements it would be impossible to handle the weights that are met with in machinery of the present day.

I now come to one class of machine which, humble and small as it is, has probably had a greater effect upon industry and upon domestic life than almost any other. I mean the *Sewing Machine.* In 1831 there was no means of making a seam except by the laborious process of the hand needle. In 1846 Eldred Walker patented a machine for passing the basting thread through the gores of umbrellas—a machine which was very ingenious and very simple, but utterly unlike the eye-pointed needle sewing machine of the present day, using sometimes two threads—the second being put in by a shuttle or by another needle—and making stitches at twentyfold the rapidity with which the most expert needlewoman could work. By means of the sewing-machine not only are all textile fabrics operated upon, but even the thickest leather is dealt with, and, as a *tour de force*, but as a matter of fact, sheet-iron plates themselves have been pierced and have been united by a seam no boiler-maker ever contemplated, the piercing and the seam being produced by a Blake sewing machine. I believe all in this Section will agree that the use of the sewing machine has been unattended by loss to those who earn their living by the needle—in fact, it would not be too much to say that there has been a positive improvement in their wages.

The next matter I have to touch upon is that of *Agricultural Machinery.* In 1831 we had threshing machines and double ploughs, and even multiple ploughs had been proposed, tried, and abandoned. Reaping machines had been experimented with and abandoned; sowing machines were in use, but not many of them; clod-crushers and horse-rakes were also in use, but, as a fact, ploughing was done by horse-power a single furrow at a time, mowing and reaping were done by the scythe or the sickle, sheaves were bound by hand, hay was tedded by hand-rakes, while all materials and produce were moved about in carts and waggons drawn by horses. At the present time we have multiple ploughs, making five or six furrows at a time; these, and cultivators also, being driven by steam, commonly from two engines, one on each headland, the plough being in between, and being worked backward and forward by a rope from each engine alternately; or, one engine only is used, with a capstan on the other headland, by another mode known as the roundabout system, where the engine is fixed, and the rope carried round about the field. Or else ploughs and cultivators are worked by ropes from two capstans placed on the two headlands, and driven by means of a light quick-going rope, actuated by an engine the position of which is not changed. And then we have reaping machines, worked at present by horses, but how long it will be before the energy residing in a battery or that in a reservoir of compressed air will supersede horse-power, to drive the reaping-machine, I don't know, but I don't suppose it will be very long. The mowing and reaping machines not only cut the crop and distribute it in swathes—in the case of the reaping machine in bundles, but now, in the instance of these latter machines, are competent to bind it into sheaves. In lieu of hand-tedding hay-making machines are employed, tossing the grass into the air so as to thoroughly aërate it, taking advantage of every brief interval of fine weather; and seeds and manure are distributed by machine with unfailing accuracy. The soil is drained by the aid of properly constructed ploughs for preparing the trenches, roots are steamed and sliced as food for cattle, and the threshing machine no longer merely beats out the grain, but screens it, separates it, and elevates the straw so as to mechanically build it up into a stack. I don't know a better class of machine than the agricultural portable engine. Every part of it is perfectly proportioned and made; it is usually of the locomotive type; and the economy of fuel in its use is extremely great. I cannot help thinking that the improvement in this respect which has taken place in these engines, and the improvement of agricultural machinery generally, is very largely due to the Royal Agricultural Society, one of the most enterprising bodies in England.

I now come to the very last subject I propose to speak upon, and that is *Printing Machinery*, and especially as applied to the printing of newspapers. In 1831 we had the steam press, sending out a few hundred copies in an hour, and doing that upon detached sheets; and thus many hours were required for an edition of some thousands. The only way in those days of expediting the matter would have been to have recomposed the paper, involving, however, double labour to the compositors, and a double chance of error. At the present day we have by the Walter Press the paper printed on a continuous sheet, at a rate per hour at least three times as great as that of the presses of 1831; and, by the aid of papier-mâché moulds, within five minutes from the starting of the first press, a second press can be provided with its stereotype plates and got to work, and a third one in the next five minutes; and thus the wisdom of our senators, which has been delivered as late as three o'clock in the morning, is ready to be transmitted by the newspaper train leaving Euston at 5.15 a.m.

This is the last subject with which I shall trouble the Section. I have purposely omitted telegraphy; I have purposely omitted artillery, textile fabrics, and the milling and preparation of grain. These and other matters I have omitted for several reasons. Some I have omitted because I was incompetent to speak upon them, others because of the want of time, and others because perhaps they more properly belong to Section A.

I hope, Sir, although your address, dealing with the future, was undoubtedly the right address for a President to deliver, and although it is equally right that we should not content ourselves with merely looking back in a 'rest and be thankful' spirit at the various progress which this paper records, it may, nevertheless, be thought well that there should have been brought before the Section, in however cursory a manner, some notice of Mechanical Development during the past fifty years.

TRANSACTIONS OF THE SECTIONS.

TRANSACTIONS OF THE SECTIONS.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section—
Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S.L. and E.

THURSDAY, SEPTEMBER 1.

The President delivered the following Address:—

On the Sources of Energy in Nature available to Man for the Production of Mechanical Effect.

During the fifty years' life of the British Association, the Advancement of Science for which it has lived and worked so well has not been more marked in any department than in one which belongs very decidedly to the Mathematical and Physical Section—the science of Energy. The very name energy, though first used in its present sense by Dr. Thomas Young about the beginning of this century, has only come into use practically after the doctrine which defines it had, during the first half of the British Association's life, been raised from a mere formula of mathematical dynamics to the position it now holds of a principle pervading all nature and guiding the investigator in every field of science.

A little article communicated to the Royal Society of Edinburgh a short time before the commencement of the epoch of energy under the title 'On the Sources Available to Man for the Production of Mechanical Effect'[1] contained the following:—

'Men can obtain mechanical effect for their own purposes by working mechanically themselves, and directing other animals to work for them, or by using natural heat, the gravitation of descending solid masses, the natural motions of water and air, and the heat, or galvanic currents, or other mechanical effects produced by chemical combination, but in no other way at present known. Hence the stores from which mechanical effect may be drawn by man belong to one or other of the following classes:—

'I. The food of animals.

'II. Natural heat.

'III. Solid matter found in elevated positions.

'IV. The natural motions of water and air.

'V. Natural combustibles (as wood, coal, coal-gas, oils, marsh-gas, diamond, native sulphur, native metals, meteoric iron).

'VI. Artificial combustibles (as smelted or electrically-deposited metals, hydrogen, phosphorus).

'In the present communication, known facts in natural history and physical science, with reference to the sources from which these stores have derived their mechanical energies, are adduced to establish the following general conclusions:—

'1. *Heat radiated from the sun* (sunlight being included in this term) *is the principal source of mechanical effect available to man.*[2] From it is derived the whole

[1] Read at the Royal Society of Edinburgh on February 2, 1852 (*Proceedings* of that date).

[2] A general conclusion equivalent to this was published by Sir John Herschel in 1833. See his *Astronomy*, edit. 1849, § (399).

mechanical effect obtained by means of animals working, water-wheels worked by rivers, steam-engines, galvanic engines, windmills, and the sails of ships.

'2. The motions of the earth, moon, and sun, and their mutual attractions, constitute an important source of available mechanical effect. From them all, but chiefly no doubt from the earth's motion of rotation, is derived the mechanical effect of water-wheels driven by the tides.

'3. The other known sources of mechanical effect available to man are either terrestrial—that is, belonging to the earth, and available without the influence of any external body—or meteoric—that is, belonging to bodies deposited on the earth from external space. Terrestrial sources, including mountain quarries and mines, the heat of hot springs, and the combustion of native sulphur, perhaps also the combustion of inorganic native combustibles, are actually used; but the mechanical effect obtained from them is very inconsiderable, compared with that which is obtained from sources belonging to the two classes mentioned above. Meteoric sources, including only the heat of newly-fallen meteoric bodies, and the combustion of meteoric iron, need not be reckoned among those available to man for practical purposes.'

Thus we may summarise the natural sources of energy as Tides, Food, Fuel, Wind, and Rain.

Among the practical sources of energy thus exhaustively enumerated, there is only one not derived from sun-heat—that is the tides. Consider it first. I have called it *practical*, because tide-mills exist. But the places where they can work usefully are very rare, and the whole amount of work actually done by them is a drop to the ocean of work done by other motors. A tide of two meters' rise and fall, if we imagine it utilised to the utmost by means of ideal water-wheels doing with perfect economy the whole work of filling and emptying a dock-basin in infinitely short times at the moments of high and low water, would give just one metre-ton per square metre of area. This work done four times in the twenty-four hours amounts to 1-1620th of the work of a horse-power. Parenthetically, in explanation, I may say that the French metrical equivalent (to which in all scientific and practical measurements we are irresistibly drawn, notwithstanding a dense barrier of insular prejudice most detrimental to the islanders),—the French metrical equivalent of James Watt's 'horse-power' of 550 foot-pounds per second, or 33,000 foot-pounds per minute, or nearly two million foot-pounds per hour, is 75 metre-kilogrammes per second, or 4½ metre-tons per minute, or 270 metre-tons per hour. The French ton of 1,000 kilogrammes used in this reckoning is 0·984 of the British ton.

Returning to the question of utilising tidal energy, we find a dock area of 162,000 square metres (which is little more than 400 metres square) required for 100 horse-power. This, considering the vast costliness of dock construction, is obviously prohibitory of every scheme for economising tidal energy by means of artificial dock-basins, however near to the ideal perfection might be the realised tide-mill, and however convenient and non-wasteful the accumulator—whether Faure's electric accumulator, or other accumulators of energy hitherto invented or to be invented—which might be used to store up the energy yielded by the tide-mill during its short harvests about the times of high and low water, and to give it out when wanted at other times of six hours. There may, however, be a dozen places possible in the world where it could be advantageous to build a sea-wall across the mouth of a natural basin or estuary, and to utilise the tidal energy of filling it and emptying it by means of sluices and water-wheels. But if *so* much could be done, it would in many cases take only a little more to keep the water out altogether, and make fertile land of the whole basin. Thus we are led up to the interesting economical question, whether is forty acres (the British *agricultural* measure for the area of 162,000 square metres) or 100 horse-power more valuable. The annual cost of 100 horse-power night and day, for 365 days of the year, obtained through steam from coals, may be about ten times the rental of forty acres at 2*l.* or 3*l.* per acre. But the value of land is essentially much more than its rental, and the rental of land is apt to be much more than 2*l.* or 3*l.* per acre in places where 100 horse-power could be taken with advantage from coal through steam. Thus the question remains unsolved, with the possibility that in one place the answer may be *one hundred horse-power*, and in another *forty acres*. But, indeed, the question is hardly worth answering, considering the rarity of the cases, if they exist at all, where embankments for the utilisation of tidal energy are practicable.

Turning now to sources of energy derived from sun-heat, let us take the wind first. When we look at the register of British shipping and see 40,000 vessels, of which about 10,000 are steamers and 30,000 sailing ships, and when we think how vast an absolute amount of horse-power is developed by the engines of those steamers, and how considerable a proportion it forms of the whole horse-power taken from coal annually in the whole world at the present time, and when we consider the sailing ships of other nations, which must be reckoned in the account, and throw in the little item of windmills, we find that, even in the present days of steam ascendency, old-fashioned Wind still supplies a large part of all the energy used by man. But however much we may regret the time when Hood's young lady, visiting the fens of Lincolnshire at Christmas, and writing to her dearest friend in London (both sixty years old now if they are alive), describes the delight of sitting in a bower and looking over the wintry plain, not desolate, because 'windmills lend revolving animation to the scene,' we cannot shut our eyes to the fact of a lamentable decadence of wind-power. Is this decadence permanent, or may we hope that it is only temporary? The subterranean coal-stores of the world are becoming exhausted surely, and not slowly, and the price of coal is upward bound—upward bound on the whole, though no doubt it will have its ups and downs in the future as it has had in the past, and as must be the case in respect to every marketable commodity. When the coal is all burned; or, long before it is all burned, when there is so little of it left and the coal-mines from which that little is to be excavated are so distant and deep and hot that its price to the consumer is greatly higher than at present, it is most probable that windmills or wind-motors in some form will again be in the ascendant, and that wind will do man's mechanical work on land at least in proportion comparable to its present doing of work at sea.

Even now it is not utterly chimerical to think of wind superseding coal in some places for a very important part of its present duty—that of giving light. Indeed, now that we have dynamos and Faure's accumulator, the little want to let the thing be done is cheap windmills. A Faure cell containing 20 kilogrammes of lead and minium charged and employed to excite incandescent vacuum-lamps has a light-giving capacity of 60-candle hours (I have found considerably more in experiments made by myself; but I take 60 as a safe estimate). The charging may be done uninjuriously, and with good dynamical economy, in any time from six hours to twelve or more. The drawing-off of the charge for use may be done safely, but somewhat wastefully, in two hours, and very economically in any time of from five hours to a week or more. Calms do not last often longer than three or four days at a time. Suppose, then, that a five days' storage-capacity suffices (there may be a little steam-engine ready to set to work at any time after a four-days' calm, or the user of the light may have a few candles or oil-lamps in reserve, and be satisfied with them when the wind fails for more than five days). One of the twenty kilogramme cells charged when the windmill works for five or six hours at any time, and left with its 60-candle hours' capacity to be used six hours a day for five days, gives a 2-candle light. Thus thirty-two such accumulator cells so used would give as much light as four burners of London 16-candle gas. The probable cost of dynamo and accumulator does not seem fatal to the plan, if the windmill could be had for something comparable with the prime cost of a steam-engine capable of working at the same horse-power as the windmill when in good action. But windmills as hitherto made are very costly machines; and it does not seem probable that, without inventions not yet made, wind can be economically used to give light in any considerable class of cases, or to put energy into store for work of other kinds.

Consider, lastly, rain-power. When it is to be had in places where power is wanted for mills and factories of any kind, water-power is thoroughly appreciated. From time immemorial, water-motors have been made in large variety for utilising rain-power in the various conditions in which it is presented, whether in rapidly-flowing rivers, in natural waterfalls, or stored at heights in natural lakes or artificial reservoirs. Improvements and fresh inventions of machines of this class still go on; and some of the finest principles of mathematical hydrodynamics have, in the lifetime of the British Association, and, to a considerable degree, with its assistance, been put in requisition for perfecting the theory of hydraulic mechanism and extending its practical applications.

A first question occurs: Are we necessarily limited to such natural sources of water-power as are supplied by rain falling on hill-country, or may we look to the collection of rain-water in tanks placed artificially at sufficient heights over flat country to supply motive power economically by driving water-wheels? To answer it: Suppose a height of 100 metres, which is very large for any practicable building, or for columns erected to support tanks; and suppose the annual rainfall to be three-quarters of a metre (30 inches). The annual yield of energy would be 75 metre-tons per square metre of the tank. Now one horse-power for 365 times 24 hours is 236,500 foot-tons; and therefore (dividing this by 75) we find 3,153 square metres as the area of our supposed tank required for a continuous supply of one horse-power. The prime cost of any such structure, not to speak of the value of the land which it would cover, is utterly prohibitory of any such plan for utilising the motive power of rain. We may or may not look forward hopefully to the time when windmills will again 'lend revolving animation' to a dull flat country; but we certainly need not be afraid that the scene will be marred by forests of iron columns taking the place of natural trees, and gigantic tanks overshadowing the fields and blackening the horizon.

To use rain-power economically on any considerable scale we must look to the natural drainage of hill country, and take the water where we find it either actually falling or stored up and ready to fall when a short artificial channel or pipe can be provided for it at moderate cost. The expense of aqueducts, or of underground water-pipes, to carry water to any great distance—any distance of more than a few miles or a few hundred yards—is much too great for economy when the yield to be provided for is *power*; and such works can only be undertaken when the *water itself* is what is wanted. Incidentally, in connection with the water-supply of towns, some part of the energy due to the head at which it is supplied may be used for power. There are, however, but few cases (I know of none except Greenock) in which the energy to spare over and above that devoted to bringing the water to where it is wanted, and causing it to flow fast enough for convenience at every opened tap in every house or factory, is enough to make it worth while to make arrangements for letting the water-power be used without wasting the water-substance. The cases in which water-power is taken from a town supply are generally very small, such as working the bellows of an organ, or 'hair-brushing by machinery,' and involve simply throwing away the used water. The cost of energy thus obtained must be something enormous in proportion to the actual quantity of the energy, and it is only the smallness of the quantity that allows the convenience of having it when wanted at any moment, to be so dearly bought.

For anything of great work by rain-power, the water-wheels must be in the place where the water-supply with natural fall is found. Such places are generally far from great towns, and the time is not yet come when great towns grow by natural selection beside waterfalls, for power; as they grow beside navigable rivers, for shipping. Thus hitherto the use of water-power has been confined chiefly to isolated factories which can be conveniently placed and economically worked in the neighbourhood of natural waterfalls. But the splendid suggestion made about three years ago by Mr. Siemens in his presidential address to the Institution of Mechanical Engineers, that the power of Niagara might be utilised, by transmitting it electrically to great distances, has given quite a fresh departure for design in respect to economy of rain-power. From the time of Joule's experimental electro-magnetic engines developing 90 per cent. of the energy of a Voltaic battery in the form of weights raised, and the theory of the electro-magnetic transmission of energy completed thirty years ago on the foundation afforded by the train of experimental and theoretical investigations by which he established his dynamical equivalent of heat in mechanical, electric, electro-chemical, chemical, electro-magnetic, and thermoclastic phenomena, it had been known that potential energy from any available source can be transmitted electro-magnetically by means of an electric current through a wire, and directed to raise weights at a distance, with unlimitedly perfect economy. The first large-scale practical application of electro-magnetic machines was proposed by Holmes in 1854, to produce the electric light for lighthouses, and persevered in by him till he proved the availability of his machine to the satisfaction of the Trinity House and the delight of Faraday in trials at Blackwall in April, 1857, and it was applied to light the South Foreland lighthouse on December 8, 1858. This gave the impulse to invention; by which the electro-magnetic machine has been brought from the physical laboratory into the province of engineering, and has sent back to the realm of pure science a beautiful discovery—that of the fundamental principle of the dynamo, made triply and independently, and as nearly as may be simultaneously, in 1867 by Dr. Werner Siemens, Mr. S. A. Varley, and Sir Charles Wheatstone; a discovery which constitutes an electro-magnetic analogue to the fundamental electrostatic principle of Nicholson's revolving doubler, resuscitated by Mr. C. F. Varley in his instrument 'for generating electricity;' patented in 1860; and by Holtz in his celebrated electric machine; and by myself in my 'replenisher' for multiplying and maintaining charges in Leyden jars for heterostatic electrometers, and in the electrifier for the siphon of my recorder for submarine cables.

The dynamos of Gramme and Siemens, invented and made in the course of these fourteen years since the discovery of the fundamental principle, give now a ready means of realising economically on a large scale, for many important practical applications, the old thermo-dynamics of Joule in electro-magnetism; and, what particularly concerns us now in connection with my present subject, they make it possible to transmit electro-magnetically the work of waterfalls through long insulated conducting wires, and use it at distances of fifties or hundreds of miles from the source, with excellent economy—better economy, indeed, in respect to proportion of energy used to energy dissipated than almost anything known in ordinary mechanics and hydraulics for distances of hundreds of yards instead of hundreds of miles.

In answer to questions put to me in May, 1879,[1] by the Parliamentary Committee on Electric Lighting, I gave a formula for calculating the amount of energy transmitted, and the amount dissipated by being converted into heat on the way, through an insulated copper conductor of any length, with any given electro-motive force applied to produce the current. Taking Niagara as example, and with the idea of bringing its energy usefully to Montreal, Boston, New York, and Philadelphia, I calculated the formula for a distance of 300 British statute miles (which is greater than the distance of any of those four cities from Niagara, and is the radius of a circle covering a large and very important part of the United States and British North America), and found almost to my surprise that, even with so great a distance to be provided for, the conditions are thoroughly practicable with good economy, all aspects of the case carefully considered. The formula itself will be the subject of a technical communication to Section A in the course of the Meeting on which we are now entering. I therefore at present restrict myself to a slight statement of results.

1. Apply dynamos driven by Niagara to produce a difference of potential of 80,000 volts between a good earth-connection and the near end of a solid copper wire of half an inch (1·27 centimetre) diameter, and 300 statute miles (483 kilometres) length.

2. Let resistance by driven dynamos doing work, or by electric lights, or, as I can now say, by a Faure battery taking in a charge, be applied to keep the remote end at a potential differing by 64,000 volts from a good earth-plate there.

3. The result will be a current of 240 webers through the wire taking energy from the Niagara end at the rate of 26,250 horse-power, losing 5,250 (or 20 per

[1] Printed in the Parliamentary Blue Book Report of the Committee on Electric Lighting, 1879.

cent.) of this by the generation and dissipation of heat through the conductor and 21,000 horse-power (or 80 per cent. of the whole) on the recipients at the far end.

4. The elevation of temperature above the surrounding atmosphere, to allow the heat generated in it to escape by radiation and be carried away by convection is only about 20° Centigrade; the wire being hung freely exposed to air like an ordinary telegraph wire supported on posts.

5. The striking distance between flat metallic surfaces with difference of potentials of 80,000 volts (or 75,000 Daniell's) is (Thomson's 'Electrostatics and Magnetism,' § 340) only 18 millimetres, and therefore there is no difficulty about the insulation.

6. The cost of the copper wire, reckoned at 8*d.* per lb., is 37,000*l.*; the interest on which at 5 per cent. is 1,900*l.* a year. If 5,250 horse-power at the Niagara end costs more than 1,900*l.* a year, it would be better economy to put more copper into the conductor; if less, less. I say no more on this point at present, as the economy of copper for electric conduction will be the subject of a special communication to the Section.

I shall only say, in conclusion, that one great difficulty in the way of economising the electrical transmitting power to great distances (or even to moderate distances of a few kilometres) is now overcome by Faure's splendid invention. High potential—as Siemens, I believe, first pointed out—is the essential for good dynamical economy in the electric transmission of power. But what are we to do with 80,000 volts when we have them at the civilised end of the wire? Imagine a domestic servant going to dust an electric lamp with 80,000 volts on one of its metals! Nothing above 200 volts ought on any account ever to be admitted into a house or ship or other place where safeguards against accident cannot be made absolutely and for ever trustworthy against all possibility of accident. In an electric workshop 80,000 volts is no more dangerous than a circular saw. Till I learned Faure's invention I could but think of step-down dynamos, at a main receiving station, to take energy direct from the electric main with its 80,000 volts, and supply it by secondary 200-volt dynamos or 100-volt dynamos, through proper distributing wires, to the houses and factories and shops where it is to be used for electric lighting, and sewing-machines, and lathes, and lifts, or whatever other mechanism wants driving power. Now the thing is to be done much more economically, I hope, and certainly with much greater simplicity and regularity, by keeping a Faure battery of 40,000 cells always being charged direct from the electric main, and applying a methodical system of removing sets of 50, and placing them on the town-supply circuits, while other sets of 50 are being regularly introduced into the great battery that is being charged, so as to keep its number always within 50 of the proper number, which would be about 40,000 if the potential at the emitting end of the main is 80,000 volts.

The following Papers were read:—

1. *On the Possibility of the Existence of Intra-Mercurial Planets.*[1] *By* Balfour Stewart, *LL.D., F.R.S.*

It is a somewhat frequent speculation amongst those engaged in sun-spot research to regard the state of the solar surface as influenced in some way by the positions of the planets.

In order to verify this hypothesis, observers have tried whether there appear to be solar periods exactly coinciding with certain well-known planetary periods.

This method has been adopted by the Kew observers (Messrs. De La Rue, Stewart, and Loewy), who had an unusually large mass of material at their disposal, and they have obtained from it the following results:—

1. An apparent maximum and minimum of spotted area approximately corresponding in time to the perihelion and aphelion of Mercury.

[1] Published *in extenso* in *Nature* September 15, 1881.

2. An apparent maximum and minimum of spotted area approximately corresponding in time to the conjunction and opposition of Mercury and Jupiter.

3. An apparent maximum and minimum of spotted area approximately corresponding in time to the conjunction and opposition of Venus and Jupiter.

4. An apparent maximum and minimum of spotted area approximately corresponding in time to the conjunction and opposition of Venus and Mercury.

Whatever truth there may be in these conclusions, it appears to be quite certain that periodical relations between the various *known* planets will not account for *all* the sun-spot inequalities with which we are acquainted. They may account for some, but certainly not for all. For there are solar inequalities of short duration, which, presuming them to be real, can only be accounted for on the planetary hypothesis by supposing the existence of several unknown intra-mercurial planets.

In conjunction with Mr. William Dodgson I have devised a method for detecting unknown inequalities, which, when applied to the sun, reveals a period in sun-spots of 24·011 days. Is this the period of an intra-mercurial planet?

It is quite easy to put this hypothesis to a test, taking for our guidance the results obtained by the Kew observers. For what do these results exhibit? In the first place, they exhibit the probability of a sun-spot inequality corresponding to the period of Mercury round the sun; and in the next, they exhibit the probability of similar inequalities corresponding to the synodic period of Mercury and Venus, and to that of Mercury and Jupiter. Now, if there be an intramercurial planet of period 24·011 days, it will have the following synodic periods:—

With Mercury	33·025 days.
With Venus	26·884 "
With Jupiter	24·145 "

In conjunction with Mr. Dodgson I have applied the above method of analysis with the view of ascertaining whether there be well-marked sun-spot inequalities nearly corresponding to these periods, and we have obtained the following results:—

A very prominent inequality of period 32·955 days.
A very prominent inequality of period 26·871 "
A less prominent inequality of period 24·142 "

It will thus be noticed that there are prominent sun-spot inequalities, the periods of which agree very well with the synodic periods of the supposed planet with Mercury, Venus, and Jupiter, more especially if we bear in mind that this is only a first approximation.

The test, however, is not yet complete. Referring once more to the results of the Kew observers, it will be noticed that we have approximately maxima of sun-spot areas when Mercury and Venus, or when Mercury and Jupiter are in conjunction. Now, if we assume that there is an intra-mercurial planet of period 24·011 days, we are as yet unable to assign its exact position in ecliptical longitude at any moment. We know its period, and we may presume that it has considerable excentricity, but we know nothing else. We may, however, assume as most probable that the maximum point of the inequality of period 32·955 days corresponds to the conjunction of the planet with Mercury, and so on for the other inequalities. On this assumption, and knowing the average rate of motion of the planet in its orbit, we may decide approximately its position at a given epoch independently from each of the three synodic periods, above mentioned, and these positions ought to agree together, if our hypothesis be correct.

I have done this approximately, but am not able to bring exact figures before this meeting. The agreement is as great as can be expected, bearing in mind that we know only the average rate of motion of the planet, and not the variations of its rate, inasmuch as we are ignorant of its excentricity. I think I may state that three independent values of its position, corresponding to January 1, 1832, will be obtained, and that the mean difference of a single value from the mean of the whole will probably not be more than twenty degrees. It would thus appear from this investigation that the evidence is in favour of the sun-spot inequality of 24·011 days being due to an intra-mercurial planet.

2. *On the Photographic Spectrum of Comet 'b' 1881.* By William Huggins, *D.C.L., LL.D., F.R.S.*

[Plate XIV.]

In the years 1866 and 1868 I applied the spectroscope to the light of comets, and in the latter year I showed that the three bright bands in the visible part of the spectrum agree with the similar bright bands which are seen when an induction spark is taken in olefiant gas.[1] The same bands are also seen in the flames of many compounds of carbon. I was inclined at that time to consider that these bands were due to the vapour of carbon. Subsequent investigations which have been made on the spectra of the compounds of carbon, appear to make it probable that these bands are the spectrum of a compound of carbon with hydrogen. The observations (1868) showed the presence of carbon, probably in combination with hydrogen, in the cometary matter.

Since that time until the present year, no comet has appeared sufficiently bright to allow of the observations on its spectrum being extended to the ultra-violet region. The apparatus with which I had successfully photographed the spectra of stars was especially suited to this purpose.[2] It consists essentially of a spectroscope, furnished with a prism of Iceland spar and lenses of quartz, placed so that the slit shall be in the principal focus of a mirror 18 inches in diameter, equatorially mounted, and driven by an electrically controlled clock.

On the evening of June 24th (1881), I directed this instrument, armed with a very sensitive gelatine plate, to the head of Comet 'b,' so that the nucleus should be upon one half of the slit. After an exposure of one hour, the open half of the slit was closed, the shutter withdrawn from the other half, and the instrument was then directed to Arcturus for fifteen minutes.

After development the plate presented a very distinct spectrum of the comet, together with that of the star, for comparison.

The spectrum of the comet consists of two spectra superposed upon each other: a continuous spectrum, which extends from about F to a little distance beyond H. In this continuous spectrum can be seen the Fraunhofer lines G, h, H, K, and many others. This spectrum is therefore due to reflected solar light.

The second spectrum consists of two sets of bright lines, and a suspicion of the presence of a third set. These lines are obviously to be referred to original light from the comet.

The strongest set consists of two bright lines in the commencement of the ultra-violet region. Measures, made by the aid of the comparison star-spectrum, give for these bright lines the wave-lengths 3883 and 3870. The less refrangible line is much stronger, and a faint luminosity can be traced from it to a little beyond the second line 3870. There can be, therefore, no doubt that these lines represent the brightest end of the ultra-violet group, which appears under certain circumstances in the spectra of the compounds of carbon. Professors Liveing and Dewar have found for the strong line at the beginning of the group, the wave-length 3882·7, and for the second line 3870·5.

I am also able to see upon the continuous solar spectrum, a distinct, though fainter, impression of a group of lines between G and h. There can be little doubt that this group is the one for the least refrangible limit of which the wave-length 4220 is given by Professors Liveing and Dewar.

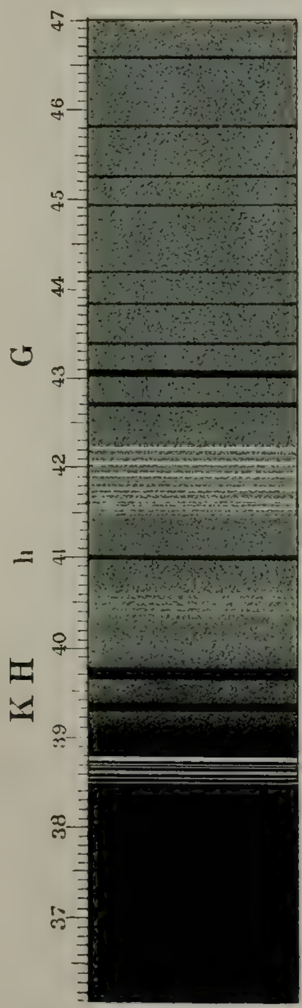
An increase of brightness in the continuous spectrum is also seen between h and H, which may be due to other bright lines, but the photograph is not strong enough to admit of any certain conclusion on this point.

On June 25, a second photograph was obtained with an exposure of an hour and a half. This photograph, notwithstanding the longer exposure, is fainter, but shows distinctly the bright lines in the ultra-violet, and the continuous spectrum.

These photographs confirm the results of my earlier observations on comets,—that part of their light is reflected sunlight, and part is original light; and, further, that carbon is present in the cometary matter. The new bright groups in the

[1] *Phil. Trans.* 1868, p. 556.

[2] *Phil. Trans.* 1880, p. 669.



Illustrating Dr. W. Huggins' Paper on Photographic Spectrum of Comet b 1881.

Spottiswoode & Co. Lith. London

comet's spectrum which the photographs have revealed to us, are certainly characteristic of substances containing carbon.

In their paper 'On the spectra of the compounds of carbon' ('Proc. Roy. Soc.' vol. xx. p. 494), Professors Liveing and Dewar bring forward evidence to show that these two groups indicate the presence of cyanogen, and are not to be seen in hydrocarbons unless nitrogen is also present. If this be the case the photograph supplies us with strong evidence of the presence of nitrogen in the comet, in addition to the carbon and hydrogen shown to be there by the bright groups in the visible region of the spectrum. It is of great interest in connection with this result, now that Schiaparelli has shown us the close relationship of meteors and comets, to mention the results of Professor Graham's experiments on the occluded gases from the meteoric iron of Lenarto ('Proc. Roy. Soc.' xv. p. 502, 1867.) This iron gave nearly three times its volume of gas, consisting chiefly of hydrogen, with small quantities of carbonic oxide and nitrogen.

Professor Wright's examination of the stony meteorites shows the oxides of carbon, chiefly the di-oxide, to be present in largest quantity, but he obtained also a small percentage of hydrogen and nitrogen ('Amer. Journ. Scien.' vol. x., July, 1875). Other kinds of meteors are known which contain hydrocarbons, even in considerable quantity. It is scarcely necessary to add that, under suitable conditions, the spectra of the gases from some meteorites will be similar to that observed from the light of comets.

Messrs. Liveing and Dewar's experiments would seem to show that a high temperature must be present in the comet, if the cyanogen is formed there, but if cyanides should be found in meteorites this necessity would not exist.

Whatever the views that may be entertained as to the forms of combination in which the carbon exists, there can be no doubt whatever of the presence of carbon in comets. I should mention that Mr. Lockyer regards the two bright groups seen in the photograph, and the three groups in the visible spectrum, to be due to the vapour of carbon at different heat-levels ('Proc. Roy. Soc.' vol. xxx. p. 461).

It is of importance to mention the strong intensity in the photograph of the lines 3883 and 3870 as compared with the continuous spectrum, and the faint bright group beginning at 4220. At this part of the spectrum, therefore, the light emitted by the cometary matter exceeded by many times the reflected solar light.

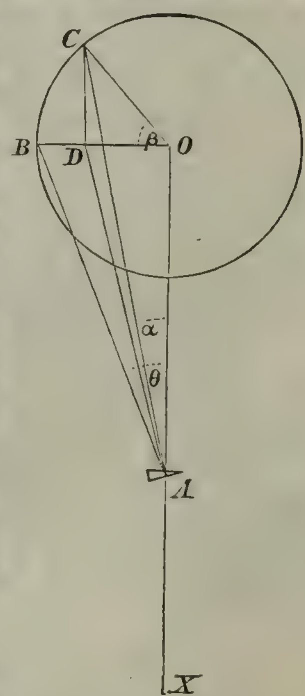
On August 21, I attempted to obtain, with an exposure of one hour, a photograph of the spectrum of a large comet which has appeared since Comet 'c' 1881. The evening was not very favourable, and the comet was at a low altitude and not so brilliant as Comet 'b.' I am not able to see on the plate more than a faint trace of the brightest lines (W. L. 3883 and 3870) of the spectrum obtained from the former comet.

---

3. *On a Prismatic Optometer.* *By* Tempest Anderson, *M.D., B.Sc.*

It is well known that in the normal eye, with its accommodation relaxed, parallel rays of light, that is, those from distant objects, are brought to a focus on the retina. Rays from near objects are divergent, and if they enter such an eye they are not brought to a focus on the retina, but would be at some point behind it. In order that they may be so brought to a focus and form a distinct image on the retina, an effort of accommodation is necessary. This is performed by a small muscle called the ciliary muscle, inside the eyeball, the ultimate effect of whose contraction is an alteration in the shape and perhaps the condition of the lens, which causes the rays to be more strongly refracted, and brings them to a focus on the retina. The effect is in fact the same as if a convex lens were added to the optical system of the eye. As age advances, the muscle and lens become stiffer and work with difficulty. They are relieved of part of their work by putting a convex glass in front of the eye. Hypermetropia is a condition in which the axis of the eyeball is too short, compared with the refracting power of the lens. In it an effort of accommodation is necessary to see even distant objects clearly, and a still stronger effort to see near objects. A person suffering from it requires convex glasses. When both eyes are used together, the optic axes of both are directed to the object, so that in looking at a distant object they are directed parallel, and in looking at a near one they converge. These movements are effected by the external muscles of the eyeball, which are supplied by branches of the same nerve as the ciliary muscle. As a fact these movements of the ciliary muscle and of the external muscles of the eyeball are associated, or habitually performed in conjunction; that is, the brain has become accustomed to send an impulse to the one set of muscles proportionate to that sent to the other. Any disturbance of this association can only be accomplished by a distinct effort which, if severe or long continued, is apt to be painful.

Suppose a man has become presbyopic, *i.e.* his accommodation has gradually become stiff, and its range reduced. In order to accommodate for rays from an object at the ordinary reading distance of ten or twelve inches, he has now to exert an effort equal perhaps to what he would have employed when young on one four inches off, but the change has been gradual, and the convergence of the eyes for twelve inches has become associated with this amount of effort. If he now use convex glasses of suitable power, the want of refracting power is supplied, the effort of accommodation is reduced to its natural amount, but the amount of convergence which has become associated with this small effort is now insufficient, and the eyes, instead of converging to twelve inches, converge on a point several feet distant, so that double vision would be produced, unless by a distinct effort the eyes were converged more, and this effort is often painful and is expressed by the term that the spectacles 'draw' the eyes. After a time new associations are formed and the spectacles can be used comfortably, but this does not happen in all cases, and for these it is necessary to grind the lenses on glasses of prismatic section. The action of the prism is so to bend the pencils of rays coming to the eyes that they appear to diverge from a point corresponding to the new focal distance of the eyes provided with the spectacles.



Sometimes the amount of prismatic effect required is calculated, but the calculation being based on general considerations does not always suit individual persons; at other times prismatic glasses from a trial case are combined with the calculated spherical, or spherical and cylindrical glasses, until one is found with which vision is comfortable.

In many cases it is not necessary to use glasses specially ground on prisms, but sufficient to move the centres of the glasses nearer together. The glass being thicker in the centre, looking through the part near the edge produces an amount of prismatic effect which is often sufficient. If concave glasses are used, as in cases of short sight, then they must be further apart than the distance of the eyes in order to produce this effect.

The object of the instrument exhibited is to find experimentally the amount of prismatic power, and the distance of the centres of the lenses, which is required in any individual case.

Two circular frames each $2\frac{1}{2}$ inches in diameter, and with teeth cut in their edges, are mounted so that the teeth gear into each other, and they can rotate freely, but in opposite directions. In the centre of each frame is mounted a prism of 18°; one of the frames is graduated, and when the graduation is at 0° the axes of the prisms are parallel, so that parallel pencils of rays falling on both are deviated both in the same direction, and still parallel. Thus when the pair of prisms are arranged horizontally in front of a pair of eyes, an object looked at appears displaced up or down, but there is no lateral deviation on either. If the frames be rotated 90° in one direction, the prisms both have their bases inwards, or, if in the other direction, both outwards, so that two pencils of rays are deviated to the full power of the prisms. In the intermediate positions part of the prismatic effect is resolved in a direction at right angles to the line joining the centres of the frames, and can be neglected as only producing parallel displacement of the image, and part is resolved in the direction of this line so as to produce apparent separation or approximation of the images. This amount is read off from the graduation which is constructed on to the following principle.

Suppose a ray of light XAO perpendicular to the plane of the paper meets the paper at O (see figure). Suppose a prism be introduced at A having an angle of deflection θ, the ray of light now falls on the paper at B.

If the prism be rotated through angle β, the ray now falls on the paper at C.

Join OB, OC, and resolve OC into vertical and horizontal co-ordinates CD, OD.

CD being neglected as described, we wish to find OD the horizontal component of the deflection.

$$\text{Since } OB = OC$$

$$\therefore \frac{OD}{OB} = \frac{OD}{OC}$$

$$\frac{\frac{OD}{OA}}{\frac{OB}{OA}} = \frac{OD}{OC}$$

$$\frac{\tan \alpha}{\tan \theta} = \cos \beta$$

$$\text{Log} \cos \beta = \text{Log} \tan \alpha - \log \tan \theta.$$

Two other frames are placed in front of the prisms. They contain grooves to hold lenses or combinations of lenses, and are graduated so that cylindrical lenses can be set at any desired angle. The frames can be separated or brought nearer with greater accuracy by a wedge, and the distance of the centres of the glasses is marked on the bearing. The whole is carried at the end of a graduated bar which carries a sliding support for an object. This bar is graduated in inches for use in calculation and also in focal lengths of a set of dioptric lenses.

A third prism is attached so that it can be placed between one of the frames and the object. When it is in position, the rays going through it to the eye appear to come from an object higher than when it is absent. Double vision is produced, and the eyes are left free to find their most comfortable position undisturbed by any effort to make the two images coalesce.

To use the instrument, the spherical and cylindrical elements of the spectacle required are first found either by some of the ordinary methods or by the ophthalmometer described in the Annual Volume for 1880, and the required lenses from the trial case put in the appropriate frames. The third prism is interposed, and an object, such as a vertical line, viewed at reading distance. If the images seen by the two eyes are exactly one above the other, the prismatic adjustment is presumably correct, the third prism is removed, and trial is made whether reading can be carried on for some time without fatigue.

If the images are slightly displaced externally, trial is made whether shifting the centres of the lenses nearer or further off, suffices to bring them into position. If so, the distance is noted and sent as a direction to the optician. If the displacement be more than can be corrected by this means, the prisms are rotated till the desired effect is produced, and the amount of prismatic deviation to be given to the proposed spectacles read off. The third prism is removed and reading practised as above.

---

4. *On the Effects of the Lunar and Solar Tide in increasing the Length of the Sidereal Day. By the* Rev. SAMUEL HAUGHTON, *M.D., F.R.S.*

---

5. *On the Effects of Oceanic Currents upon Climates. By the* Rev. SAMUEL HAUGHTON, *M.D., F.R.S.* See Reports, p. 451.

6. *On some applications of Electric Energy to Horticultural and Agricultural purposes.* *By* Dr. C. Wm. Siemens, *F.R.S.* See Reports, p. 474.

7. *On Hydrocarbons in the Solar Atmosphere.* *By* Captain Abney, *R.E., F.R.S.*

The existence of hydrocarbons in the solar atmosphere depends upon the evidence of the absorption-spectra in the infra-red region of certain hydrocarbons, which have been photographed lately by the author, in conjunction with Colonel Festing, R.E. In these spectra certain lines were mapped, which, when a large dispersive power was used, coincided with Fraunhofer's lines in the solar spectrum, agreeing with them, not only in position, but also in relative intensities. That the hydrocarbons are not due to our own atmosphere was shown by the fact that the relative intensities did not vary with a high as compared with a low sun. The 'a' group of lines in the solar spectrum was also pointed out as containing lines due to the hydrocarbons; but that, as they were faint lines, they would not materially affect the validity of any argument which might be brought against the theory should it be shown that this region altered in intensity with a high and low sun. At the same time this group should be carefully examined to see if the lines varied in intensity whilst others remained constant. The similarity of the fundamental band of the benzene series to the A and B lines was also noticed. The A line was doubtless solar, whilst the B line was, according to observation by careful spectroscopists, of telluric origin. Should it eventually prove that the A and B lines were due to hydrocarbons, one would be present in the sun and the other in our own atmosphere. To carbonic acid the latter could not be referred, since the absorption due to that gas in a length equivalent to more than that found in the atmosphere had been taken and gave absolutely no lines. If future observations showed the existence of hydrocarbon vapour in the solar regions, a very interesting problem in solar physics was opened out, to which attention would be given by the author and, he hoped, other observers, in the immediate future.

FRIDAY, SEPTEMBER 2.

The Section subdivided and the following Papers and Report were read:—

PHYSICAL DEPARTMENT.

1. *On Surface-tension and Capillary Action.* *By* Professor Osborne Reynolds, *F.R.S.*

In the first place it was pointed out that, although surface-tension has hitherto been considered as a statical or hydrostatical force only, such actions as the spreading of oil upon water exhibit phenomena, and those of a very marked kind, which depend, not on a statical force, but on the maintenance of this force while the surface is contracting at a very high velocity. And, in the second place, it was pointed out that the assumptions on which Laplace's theory of surface-tension is founded are insufficient to explain these phenomena, which suggest certain relations between the range of the inter-molecular attractive forces and the dimensions of these molecules.

It was shown that if the surface of pure water be touched at some point with a slightly oiled needle, the oil spreads out quickly in a circular patch, which patch at first extends with great rapidity. But it was not the rapidity of extension that was so much the point of remark, as the motion of the surface of the pure water before the advancing oil. In the usual way this motion is shown by a rib or slight elevation of the water immediately at the edge of the oil. When the initial surface is very clean the rib is always formed, but it only becomes apparent under peculiar circumstances. It is often apparent on the surface of a deep pool formed at a sharp bend of a stream, for instance, to anyone fishing. The more rapid flow into the pool causes ascending currents, which, spreading out at the surface, give rise to radial currents of pure water, which sweep back and hold at bay the oil or transparent scum on the surface of the rest of the pool, and which but for the outward motion would rapidly extend over the pure surface. Under these circumstances the edge of the scum is definitely marked by a fine rib, which shows itself in certain lights as though a fine gut-line were floating on the water and were carried, first in one direction and then in the other, according as the radial current or the spreading force of the scum are in the ascendant. It is difficult to render this rib apparent on the surface of water contained in a vessel, although this may be one or two feet in diameter. This may be done, but the motion which gives rise to the rib may be rendered apparent by other means,—by dusting the surface of the pure water with some insoluble powder, such as flowers of sulphur. The motion of the surface is rendered apparent by the motion of the dust. It is then seen that the dust does not fall back before the oil as though the surface of the pure water were in a general state of contraction, for there is absolutely no motion in the dust except in the immediate neighbourhood of the edge of the oil. It is as though the dust were swept back by the advancing edge of the oil; the dust, already swept up into a compact mass, coming up to each fresh particle, pushes it before it, until a bright yellow band is formed marking the edge of the oil. The result is to give the impression that the dust is being driven back by the oil—as if the oil were spreading from some inherent expansive force; but, as a matter of fact, the oil is being drawn forward by the contraction of the dust-covered surface of the pure water, and the fact that the dust does not move till the oil reaches it shows that the contraction takes place entirely at the edge of the oil in an almost infinitely narrow band.

This phenomenon of surface-contraction is very remarkable, for it would be inferred from other hydrodynamical phenomena that viscosity would to some extent resist the action of contraction, and thus tend to distribute this action over a considerable area, and that the contraction is not so distributed shows that there is virtually no resistance to contraction, or that the surface-tension at the points at which the surface is contracting is at least equal to the tension at those points of the surface which are at rest.

This conclusion implies much more than the tacit assumption, made by Laplace and subsequent writers, that the forces of cohesion obey the law of statical fluid pressure—equality in all directions. It is well known as regards other phenomena that this law holds only when fluids are at rest or in uniform motion; whereas here we have a case in which the same law holds for a portion of fluid which is moving with great rapidity relative to the fluid in its immediate neighbourhood.

Laplace's theory is founded on an assumed attraction, between the molecules, which attraction does not extend to sensible distances, and on the tacit assumption already mentioned, that the pressure, whether impressed or molecular, is equal in all directions. To explain the apparent absence of viscosity in the dynamical phenomena some further assumptions are necessary. If the force of cohesion is due to molecular attraction these dynamical phenomena require that the molecules under their mutual attractions should not be in a state of equilibrium, except in so far as they are held by the forces transmitted from one part of the fluid to another.

Such a condition would exist if the range of attraction extended beyond the distance of a single molecule, that is, if the molecules are spherical or in such a state of motion that they cannot fit like bricks. But whatever might be the shape of the molecules, if the forces of cohesion acted between adjacent molecules only, then they would be in equilibrium in all positions; there would be no instability and no rapid contraction, although, according to Laplace's theory, the force would be sufficient to prevent extension of the surface, and hence to explain the statical phenomena of capillary tension such as the suspension of drops. It is therefore argued that these dynamical phenomena are important, as throwing a certain amount of light on the character of the forces which cause cohesion between molecules.

2. *On some Colour Experiments.*[1] *By* Lord Rayleigh, *F.R.S.*

3. *On a Question in the Theory of Lighting.* *By* Lord Rayleigh, *F.R.S.*

It is known that a large part of the radiation from terrestrial sources is non-luminous. Even in the case of the electric arc the obscure radiation amounts, according to Tyndall, to eight-ninths of the whole, and of the remainder probably no inconsiderable part is to be found in the extreme red rays of feeble luminosity. For practical purposes this obscure radiation is useless; and the question forces itself upon us, whether or no there is any necessity, absolutely inherent in the case, for so large a proportion of waste. The following arrangement, not of course proposed as practical, seems to prove that the question should be answered in the negative.

Conceive a small spherical body of infusible material, to which energy can be communicated by electricity or otherwise, to be surrounded by a concentric reflecting spherical shell. Under these circumstances no energy can escape; but if a small hole be pierced in the shell, radiation will pass through it. In virtue of the suppositions which we have made, the emergent beam will be of small angle, and may be completely dealt with at a moderate distance by a prism and lens. Let us suppose then that a spectrum of the hole is formed and received upon a reflecting plate so held at the focus as to return the rays upon the lens and prism. These rays will re-enter the hole, and impinge upon the radiating body, which is thus again as completely isolated as if the shell were unperforated. We have now only to suppose a portion of the focal plate to be cut away in order to have an apparatus from which only one kind of radiation can escape. Whatever energy is communicated to the internal body must ultimately undergo transformation into radiation of the selected kind.

4. *On some uses of Faure's Accumulator in connection with Lighting by Electricity.* *By* Professor Sir William Thomson, *M.A.*, *F.R.S.*

The largest use of Faure's accumulator in electric lighting was to allow steam or other motive power, driving dynamos, to work economically all day, or throughout the twenty-four hours where the circumstances were such as to render this economical, and storing up energy to be drawn upon when the light was required. There was also a very valuable use of the accumulator in its application as an adjunct to the dynamo, regulating the light-giving current and storing up an irregular surplus in such a manner that stoppage of the engine would not stop the light, but only reduce it slightly, and that there would always be a good residue of two or three hours' supply of full lighting power, or a supply for eight or ten hours of light for a diminished number of lamps. He showed an automatic instrument which he had designed and constructed to break and make the circuit between the Faure battery and the dynamo, so as automatically to fulfil the conditions described in the paper. This instrument also guarded the coils of the dynamo from damage, and the accumulator battery from loss, by the current flowing back, if at any moment the electro-motive force of the dynamo flagged so much as to be overpowered by the battery.

5. *On the Economy of Metal in Conductors of Electricity.* *By* Professor Sir William Thomson, *M.A.*, *F.R.S.*

The most economical size of the copper conductor for the electric transmission of energy, whether for the electric light or for the performance of mechanical work, would be found by comparing the annual interest of the money value of the copper with the money value of the energy lost annually in the heat generated in it by the electric current. The money value of a stated amount of energy had not

[1] Published *in extenso* in *Nature*, Nov. 17, 1881.

yet begun to appear in the City price-lists. If 10*l.* were taken as the par value of a horse-power night and day for a year, and allowing for the actual value being greater or less (it might be very much greater or very much less) according to circumstances, it was easy to estimate the right quantity of metal to be put into the conductor to convey a current of any stated strength, such as the ordinary strength of current for the powerful arc light, or the tenfold strength current (of 240 webers) which the author had referred to in his address as practically suitable for delivering 21,000 horse-power of Niagara at 300 miles from the fall.

He remarked that (contrary to a very prevalent impression and belief) the gauge to be chosen for the conductor does not depend on the length of it through which the energy is to be transmitted. It depends solely on the strength of the current to be used, supposing the cost of the metal and of a unit of energy to be determined.

Let A be the sectional area of the conductor; s the specific resistance (according to bulk) of the metal; and c the strength of the current to be used. The energy converted into heat and so lost, per second per centimetre, is sc^2/A ergs.

Let p be the proportion of the whole time during which, in the course of a year, this current is kept flowing. There being 31½ million seconds in a year, the loss of energy per annum is

$$31{\cdot}5 \times 10^6 psc^2/A \text{ ergs} \qquad (1)$$

The cost of this, if E be the cost of an erg, is

$$31{\cdot}5 \times 10^6 psc^2\, E/A \qquad (2)$$

Let V be the money value of the metal per cubic centimetre, the cost of possessing it, per centimetre of length of the wire, at 5 per cent. per annum, is

$$VA/20 \qquad (3)$$

Hence the whole annual cost, by interest on the value of the metal, and by loss of energy in it, is

$$\frac{1}{20}VA + \frac{31{\cdot}5 \times 10^6 psc^2 E}{A} \qquad (4)$$

The amount of A to make this a minimum (which is also that which makes the two constituents of the loss equal) is as follows:—

$$A = \sqrt{\left(31{\cdot}5 \,.\, 10^6 psc^2 E/\frac{V}{20}\right)}$$
$$= c\sqrt{(63 \,.\, 10^7 psE/V)} \qquad (5)$$

Taking 70*l.* per ton as the price of copper of high conductivity (known as 'conductivity copper' in the metal market), we have ·00007*l.* as the price of a gramme. Multiplying this by 8·9 (the specific gravity of copper), we find, as the price of a cubic centimetre,

$$V = {\cdot}00062l. \qquad (6)$$

and the assumption of 10*l.* as the par value of one horse-power day and night for 365 days, gives, as the price of an erg,

$$10l./(31\tfrac{1}{2} \times 10^6 \times 74 \times 10^8) = \frac{1}{23 \times 10^{14}} \text{ of } 1l. \qquad (7)$$

Supposing the actual price to be at the rate of $e \times 10l.$ per year, per horse-power we have

$$E = \frac{e}{23 \times 10^{14}} \text{ of } 1l. \qquad (8)$$

Lastly, for the specific resistance of copper we have

$$s = 1640 \qquad (9)$$

Using (8) and (9) in (5) we find,

$$A = c\sqrt{\frac{63 \times 10^7 \times 1640 \times pe}{23 \times 10^{15} \times {\cdot}00062}} = c\sqrt{\frac{pe}{1{\cdot}38}} \qquad (10)$$

Suppose, for example, $p = {\cdot}5$ (that is, electric work through the conductor for twelve hours of every day of the year to be provided for), and $e = 1$. These suppositions correspond fairly well to ordinary electric transmission of energy in towns for light, according to present arrangements. We have—

$$A = c\sqrt{\frac{1}{27 \cdot 6}} = \frac{c}{5 \cdot 25} \doteqdot \cdot 19.c$$

That is to say, the sectional area of the wire in centimetres ought to be about a fiftieth of the strength of the current in webers. Thus, for a powerful arc-light current of 21 webers, the sectional area of the leading wire should be ·4 of a square centimetre, and therefore its diameter (if it is a solid round wire) should be ·71 of a centimetre.

If we take $e = \frac{1}{27 \cdot 6}$, which corresponds to 1,900*l.* a year as the cost of 5,250 horse-power (see Presidential Address, Section A, p. 518), and if we take $p = 1$, that is reckon for continued night and day electric work through the conductor, we have—

$$A = \frac{c}{\sqrt{381}} \doteqdot \frac{c}{19 \cdot 5}:$$

and if $c = 24$, $A = 1 \cdot 24$, which makes the diameter 1·26 centimetres, or half an inch (as stated in the Presidential Address). But even at Niagara it is not probable that the cost of an erg can be as small as $\frac{1}{28}$ of what we have taken as the par value for England ; and probably therefore a larger diameter for the wire than $\frac{1}{2}$ inch will be better economy if so large a current as 240 webers is to be conducted by it.

---

6. *On the proper Proportions of Resistance in the Working Coils, the Electro-Magnets, and the External Circuits of Dynamos. By* Professor Sir WILLIAM THOMSON, *M.A., F.R.S.*

For the electro-magnet;

Let L be the length of the wire,

B ,, bulk of the whole space occupied by wire and insulation,

n ,, ratio of this whole space to the bulk of the copper alone (that is, let $\frac{1}{n}B$ be the bulk of the copper),

A ,, the sectional area of wire and insulator,

R ,, the resistance of the wire.

For the working coil, let the corresponding quantities be L', B', n', R'. Lastly, let s be the specific resistance of the copper. We have—

$$B = AL$$

$$R = ns\frac{L}{A} = ns\frac{B}{A^2}.$$

Hence,
$$A = \frac{\sqrt{(nsB)}}{\sqrt{R}} = \frac{K}{\sqrt{R}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and similarly,
$$A' = \frac{\sqrt{(n's'B')}}{\sqrt{R'}} = \frac{K'}{\sqrt{R'}} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where K and K' denote constants.

Now, let c be the current through the magnet coil, and c' that through the working coil, and let v be the velocity of any chosen point of the working coil. Denoting by p the average electro-motive force between the two ends of the working coil, we have—

$$p = I\frac{c}{A}\frac{1}{A'}v \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where I is a quantity depending on the forms, magnitudes, and relative positions of B and B', and on the magnetic susceptibility of iron ; diminishing as the susceptibility diminishes with increased strength of current, or with any change of R and R' which gives increase of magnetising force.

In the single-circuit dynamo (that is, the ordinary dynamo) c' is equal to c, but not so in the shunt-dynamo. In each, the whole electric activity (that is, the rate of doing work) is pc'; or, by (3)—

$$I\frac{cc'}{AA'}v \qquad (4)$$

or, by (1) and (2)—

$$\frac{I\sqrt{(RR')}cc'v}{KK'} \qquad (5)$$

Of this whole work, the proportions which go to waste in heating the coils and to work in the external circuit are—

$$Rc^2+R'c'^2 \quad . \quad . \text{ waste} \qquad (6)$$

$$\frac{I\sqrt{(RR')}cc'v}{KK'}-(Rc^2+R'c'^2) \quad . \text{ useful work} \qquad (7)$$

By making v sufficiently great, the ratio of (6) to (7) (waste to useful work) may be made as small as we please. Our question is, how ought R and R' to be proportioned to make the ratio of waste to work a minimum, with any given speed? or, which comes to the same thing, to make the speed required for a given ratio of work to waste a minimum? To answer it, let r be the ratio of the whole work to the waste. We have, by (5) and (6)—

$$r=\frac{I\sqrt{(RR')}cc'}{Rc^2+R'c'^2}\ \frac{v}{KK'} \qquad (8)$$

For the single-circuit dynamo we have $c=c'$, and (8) becomes—

$$r=\frac{I\sqrt{(RR')}}{R+R'}\ \frac{v}{KK'} \qquad (9)$$

or

$$r=\frac{I\sqrt{\{R(S-R)\}}v}{SKK'} \qquad (10)$$

where

$$S=R+R' \qquad (11)$$

Suppose now S to be given, and suppose for a moment I to be constant. The problem of making r a maximum with v given, or v a minimum with r given, requires simply that $R(S-R)$ be a maximum; which it is when $R=\frac{1}{2}S$, that is, when the resistances in the working coil and the electro-magnet are equal. But in reality I is not constant; it diminishes with increase of the magnetising force. As it generally depends chiefly on the soft iron of the electro-magnet, and comparatively but little on the soft iron of the moving armature, or on iron magnetised by the current through the moving coils, it will generally be the case that I will, *cæteris paribus*, be diminished by increasing R and diminishing R'. Hence the maximum of r/v is shown by (10) to require R' to be somewhat greater than $\frac{1}{2}S$: how much greater we cannot find from the formula, without knowing the law of the variation of I.

Experience and natural selection seem to have led in most of the ordinary dynamos, as now made, to the resistance in the electro-magnet being somewhat less than the resistance in the working coil, which is in accordance with the preceding theory.

Whether the useful work of the dynamo be light-giving, or power, or heating, or electro-metallurgy, we may, for simplicity, reckon it in any possible case by referring to the convenient standard case of a current through a conductor of given resistance E connecting the working terminals of the dynamo. This conductor, in accordance with general usage, I call the 'external circuit,' which is an abbreviation for the part of the whole circuit which is external to the dynamo. In the case of the single-circuit dynamo, the current in the external circle is equal to that through the working coil and electro-magnet, or c of our notation. Hence, by Ohm's law—

$$c=\frac{p}{E+R+R'} \qquad (12)$$

or, by (3), (1), and (2),

$$c = c\frac{I\sqrt{(R R')}\,v}{K K'\,(E+R+R')} \quad . \quad . \quad . \quad . \quad . \quad (13)$$

Hence either

$$c = O \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

or

$$I = \frac{K K'\,(E+R+R')}{\sqrt{(R R')}\,v} \quad . \quad . \quad . \quad . \quad . \quad (15)$$

The case of $c = O$ is that in which

$$v < \frac{K K'(E+R+R')}{I_0\sqrt{(RR')}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

where I_0 denotes the value of I for $c = O$. To understand it, remember we are supposing no residual magnetism. For any speed subject to (16), the dynamo produces no current. When this limit is exceeded the electric equilibrium in the circuit becomes unstable; an infinitesimal current started in either direction rises rapidly in strength, till it is limited by equation (15), through the diminution of I, which it produces. Thus, regarding I as a function of c, we have in (15) the equation mathematically expressing the strength of the current maintained by the dynamo when its regular action is reached. Using (15) in (10) we find—

$$r = \frac{E+S}{S} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

which we all knew forty years ago from Joule.

In the shunt-dynamo the whole current, c', of the working coil branches into two streams, c through the electro-magnet, and $c'-c$ through the external circuit, whose strengths are inversely as the resistances of their channels. Still calling the resistance of the external circuit E, we therefore have—

$$c\,R = (c'-c)\,E, \text{ which gives } c = \frac{E}{R+E}\,c' \quad . \quad . \quad . \quad (18)$$

Hence, by Joule's original law, the expenditures of work per unit of time in the three channels are respectively

$$\left.\begin{array}{lll} R'\,c'^2 & . \quad . \quad . \quad . & \text{working coil} \\ R\left(\dfrac{E}{R+E}\right)^2 c'^2 & . & \text{electro-magnet} \\ E\left(\dfrac{R}{R+E}\right)^2 c'^2 & . & \text{external circuit} \end{array}\right\} \quad . \quad . \quad (19)$$

Hence, denoting as above by r the ratio of the whole work to the work developed in the external circuit, we have—

$$r = \frac{R' + R\left(\dfrac{E}{R+E}\right)^2 + E\left(\dfrac{R}{R+E}\right)^2}{E\left(\dfrac{R}{R+E}\right)^2} \quad . \quad . \quad . \quad (20)$$

whence

$$\left.\begin{aligned} R^2\,r &= R'\frac{(R+E)^2}{E} + R\,(R+E) \\ &= \frac{R'\,R^2}{E} + (R+R')\,E + R\,(2\,R'+R) \end{aligned}\right\} \quad . \quad . \quad (21)$$

Suppose now R and R' given, and E to be found; to make r a minimum. The solution is—

$$E = \sqrt{\frac{R'\,R^2}{R+R'}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

and this makes

$$r = 2\sqrt{\frac{R'(R+R')}{R^2}} + \frac{2R'+R}{R} \quad . \quad . \quad . \quad . \quad (23)$$

Put now

$$\frac{R'}{R} = e \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (24)$$

(22) and (23) become

$$E=\sqrt{\frac{RR'}{1+e}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

and

$$r=1+2\sqrt{\{e(1+e)\}}+2e \quad . \quad . \quad . \quad . \quad (26)$$

For good economy r must be but little greater than unity; hence e must be very small, and therefore *approximately*

$$\left.\begin{aligned} E&=\sqrt{(RR')} \\ \text{and} \quad r&=1+2\sqrt{e} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

For example, suppose the resistance of the electro-magnet to be 400 times the resistance of the working coil—that is $e=400$—and we have, approximately,

$$E=20R', \text{ and } r=1+\tfrac{1}{10}.$$

That is to say, the resistance in the external circuit is 20 times the resistance of the working coil, and the useful work in the external circuit is approximately $\frac{10}{11}$ of that lost in heating the wire in the dynamo.

---

7. *On the Application of Electricity to the Localisation of a Bullet in a Wound. By* W. H. Preece, *F.R.S.*

The object of the paper was to show how an electric current can be made an invisible and immaterial probe to determine the locality of a bullet in a wound without touching the human body. It was an application of Hughes' Induction Balance, and it had been tentatively used by Professor Graham Bell upon the President of the United States. One pair of coils was made movable, and was used for exploring the body, so as to bring the bullet in the line of the axis of the coils, the depth of the bullet being determined by a second similar bullet moved in the axis of the fixed coils until equilibrium is obtained. It was sensitive to a depth of five inches.

---

8. *On some of Bell and Tainter's recent Researches and their Consequences. By* W. Lant Carpenter, *B.A., F.C.S.*

---

9. *On the Electric Conductivity and Dichroic Absorption of Tourmaline. By* Professor Silvanus P. Thompson, *B.A., D.Sc.*

Tourmaline possesses electric conductivity differing in different directions, and, according to the author's experiments, conducts better across the optic and crystallographic axis than along it. Tourmaline also possesses the optical property of dichroism, being more opaque, in general, along the axis than across it, equal thicknesses of crystal being considered, and absorbing the ordinary ray more than the extraordinary; the different rays being unequally absorbed, giving therefore different tints in the two directions.

In the August number of the 'Philosophical Magazine' the author has treated the question of opacity of tourmaline by the aid of Maxwell's electromagnetic theory of light, and has re-written Maxwell's equations for the particular case of crystalline media in which μ, the magnetic inductive capacity, K the dielectric capacity, C the volume coefficient of electric conductivity, and V the velocity of propagation of a displacement differed in different directions. He deduces therefrom that uniaxial crystals possessing maximum conductivity along the optic axis will absorb the extraordinary ray more than the ordinary; while those possessing maximum conductivity across the axis will absorb the ordinary ray more than the extraordinary. The former is the case in positive crystals such as smoky quartz and lommellite (magnesic platinocyanide): the latter is the case in tourmaline. Maxwell's equations lead to the following formula for the relative intensity of the ordinary and extraordinary rays

$$\frac{I_O}{I_E}=\frac{\epsilon^{-\mu_2 C_2 V_2}}{\epsilon^{-\mu_1 C_1 V_1}}$$

where $\mu_1 C_1 V_1$ refer to displacements parallel to the axis; $\mu_2 C_2 V_2$ to displacements at right angles to the axis.

In dispersive media the values of V are greater for red rays than for violet waves. Hence in substances for which the axial conductivity of a medium is a maximum, the difference in the values of V for different rays will have less influence on the value of the exponential which represents the intensity of transmission of displacements parallel to that axis than on the value of the exponential which represents the intensity of transmission of displacements perpendicular to that axis. Hence in positive crystals (smoky quartz, lomellite, &c.) the dichroism takes the form of greater opacity to red than to violet rays, in the ordinary ray relatively to the extraordinary ray. In tourmaline and negative crystals, on the other hand, the opacity is greater for red than for violet in the extraordinary ray, and less for the ordinary ray. The author exhibited several specimens of coloured tourmaline cut into cubes, all of which were more opaque along the axis than across it; and in all of which the tint, as viewed along the axis, was browner than across the axis, showing in that direction an increased absorption of violet, and blue, and green rays.

The author also exhibited specimens of lomellite showing maximum opacity and maximum absorption of blue rays in a direction perpendicular to the axis. A further consequence of the theory is, that in substances in which the electric conductivity has different values along three axes there will be *trichroism.*

It also follows that dichroism is a general property of all coloured crystals in which the electric conductivities are unequal in different directions.

In conclusion it was pointed out that a mechanico-optical illustration of the behaviour of positive and negative crystals can be made as follows. A positive crystal may be represented by placing metal wires vertically in a hollow cube of glass filled with jelly or Canada balsam; while a negative crystal may be represented by horizontal layers of wire gauze fixed in a similar cube. The former conducts electricity best along a vertical axis, and is more transparent along than across that axis. The latter conducts electricity better across the axis than along it, and is more opaque to light along the axis than across it, as tourmaline is.

---

10. *On the arrangement of Cometic Perihelia with reference to the Sun's march in space.* By HENRY MUIRHEAD, *M.D.*

The author exhibited and described a diagram on which the arrangement of cometic perihelia had been laid down. This has been engraved, and the author's speculations on the mode of occurrence set forth in the 'Proceedings of the Philosophical Society of Glasgow,' vol. xiii. p. 43.

MATHEMATICAL DEPARTMENT.

1. *Second Report of the Committee appointed for the calculation of Tables of the Fundamental Invariants of Algebraic Forms.*—See Reports, p. 55.

---

2. *Report of the Committee on Mathematical Tables.*—See Reports p. 303.

---

3. *Report on Recent Progress in Hydrodynamics.*—Part 1. *By* W. M. HICKS, *M.A.*—See Reports, p. 57.

---

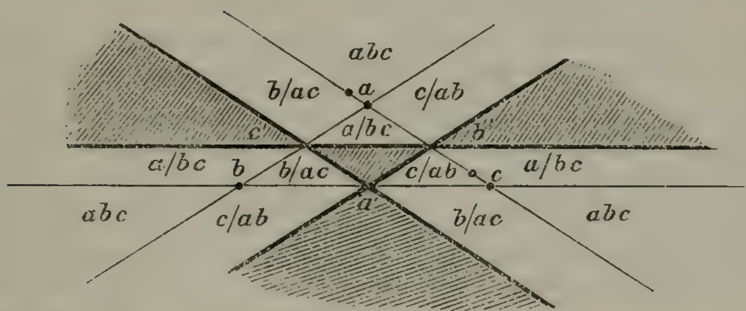
4. *Sur un critérium de Steiner relatif à la théorie des sections coniques.* *Par* M. HALPHEN.

On détermine une conique, dans un plan, par trois de ses points et par son centre, et l'on demande de distinguer les cas où cette conique est une ellipse de ceux où cette conique est une hyperbole.

Pour répondre à cette question élémentaire, Steiner a donné, sans démonstration, un très-élégant critérium[1] que je vais rappeler ici. J'en indiquerai brièvement une démonstration. J'ajouterai, pour le cas où la conique est une hyperbole, un critérium permettant de distinguer le mode de répartition des trois points donnés entre les deux branches de la courbe.

Le problème, qui consiste à déterminer une section conique par trois de ses points et par son centre, n'admet qu'une solution. Le changement du genre de la courbe, quand les données restent réelles, ce qu'on suppose, ne peut donc avoir lieu au moyen d'un passage par l'imaginaire. Le centre étant donné, le changement ne peut avoir lieu non plus au moyen du passage par le genre parabole, sans que la courbe ne dégénère en deux droites parallèles. Imaginons donc les trois points donnés comme fixes et le centre comme mobile; envisageons le lieu que doit parcourir ce centre pour que la conique dégénère de la sorte: ce lieu séparera sur le plan les régions des centres des ellipses et les régions des centres des hyperboles. Or ce lieu se compose des trois droites menées par les milieux des côtés du triangle formé par les points donnés. Il suffit d'un instant d'attention pour conclure de là le critérium de Steiner, que voici:

Soient a, b, c les trois points donnés: soient a′, b′, c′ les milieux des droites bc, ca, ab respectivement. Les droites b′c′, c′a′, a′b′ partagent le plan en sept régions. Trois de ces régions contiennent les points a, b, c. Ce sont les régions où se trouvent



les centres des hyperboles passant par a, b, c. Dans les quatre autres se trouvent les centres des ellipses.

Une demonstration analogue s'applique au critérium que j'ajoute maintenant:

Pour que les trois points a, b, c soient sur une seule et même branche d'hyperbole, il faut et il suffit que le centre soit placé dans un des angles opposés par le sommet à ceux du triangle a, b, c.

Si le centre est placé à l'intérieur du triangle a b′ c′, le point a est sur une branche d'hyperbole, les points b, c, sur l'autre. Si, de même, le centre est placé à l'intérieur d'un des triangles b c′ a′ ou ca′b′, le point b, dans le premier cas, le point c, dans le second, sont sur une branche, les deux autres sur l'autre branche.

Enfin, si le centre est placé entre un côté du triangle a b c et la parallèle à ce côté, extérieurement d'ailleurs au triangle a b c, les deux points situés sur le côté dont il s'agit sont sur une même branche, et le troisième point sur l'autre branche.

La figure suivante permet de résumer aisément ces divers résultats. Les régions des centres des ellipses sont figurées par des hachures. Dans les régions des centres des hyperboles, la répartition des points entre les branches est figurée ainsi: le symbole *a*/*bc* signifie que *a* est sur une branche, *b*, *c* sur l'autre, et le symbole *abc* signifie que les trois points sont sur une même branche.

Le critérium de Steiner et celui que je viens d'y ajouter s'appliquent sans modification au problème de la détermination d'une conique par son centre et trois de ses tangentes. Pour faire cette application, il suffira de remplacer, dans ce qui précède, les droites *bc*, *ca*, *ab* par les trois tangentes données. La démonstration se fait aussi aisément et par des procédés analogues.

[1] Démontré récemment par M. Hunyadi dans le *Journal für die reine und angewandte Mathematik*, vol. xci. p. 248.

5. *Some new Theorems on Curves of double Curvature.* *By* Professor STURM.—See Reports, p. 440.

---

6. *On Congruencies of the Second Order and Second Class.* *By* Dr. T. ARCHER HIRST, *F.R.S.*

---

7. *Sur les faisceaux de forme biquadratique binaire ayant une même Jacobienne.* *Par* CYPARISSOS STEPHANOS.

---

8. *On a Diagram connected with the Transformation of Elliptic Functions.* *By* Professor CAYLEY, *F.R.S.*

The diagram relates to a known theorem, and is constructed as follows. Consider the infinite half-plane $y = +$; draw in it, centre the origin and radius unity, a semicircle; and draw the infinite half-lines $x = -\frac{1}{2}$, and $x = \frac{1}{2}$; then we have a region included between the lines, but exterior to the semicircle. The region in question may be regarded as a curvilinear triangle, with the angles 60°, 60°, and 0°. The region may be moved parallel to itself in the direction of the axis of x, through the distance 1; say this is a 'displacement'; or we may take the 'image' of the region in regard to the semicircle. Performing any number of times, and in any order, these two operations of making the displacement and of taking the image, we obtain a new region, which is always a curvilinear triangle (bounded by circular arcs) and having the angles 60°, 60°, 0°; and the theorem is that the whole series of the new regions thus obtained completely covers, without interstices or overlapping, the infinite half-plane. The number of regions is infinite, and the size of the successive regions diminishes very rapidly. The diagram was a coloured one, exhibiting the regions obtained by a few of the successive operations.

The analytical theorem is that the whole series of transformations, ω into $\frac{a\,\omega+\beta}{\gamma\,\omega+\delta}$, where a, β, γ, δ are integers such that $a\delta-\beta\gamma=1$, can be obtained by combination of the transformations ω into $\omega+1$ and ω into $-\frac{1}{\omega}$.

---

9. *A partial Differential Equation connected with the simplest case of Abel's Theorem.* *By* Professor CAYLEY, *F.R.S.*

Consider a given cubic curve cut by a line in the points (x_1, y_1), (x_2, y_2), (x_3, y_3); taking the first and second points at pleasure, these determine uniquely the third point. Analytically, the equation of the curve determines y_1 as a function of x_1, and y_2 as a function of x_2: writing in the equation $x_3 = \lambda x_1 + (1-\lambda)x_2$ $y_3 = \lambda y_1 + (1-\lambda)\ y_2$, we have λ by a simple equation, and thence x_3; viz. x_3 is found as a function of x_1, x_2, and of the nine constants of the equation. Hence forming the derived equations (in regard to x_1, x_2) of the first, second, and third orders, we have $(1+2+3+4=)\,10$ equations from which to eliminate the 9 constants; x_3 considered as a function of x_1, x_2 thus satisfies a partial differential equation of the third order, independent of the particular cubic curve.

To obtain this equation it is only necessary to observe that we have, by Abel's theorem:

$$\frac{dx_1}{X_1}+\frac{dx_2}{X_2}+\frac{dx_3}{X_3}=0,$$

where X_1 is a given function of x_1 and y_1, that is of x_1; and X_2, X_3 are the like functions of x_2 and x_3 respectively. Hence, considering x_3 as a function of x_1, x_2, we have

$$\frac{dx_3}{dx_1}=-\frac{X_3}{X_1},\ \frac{dx_3}{dx_2}=-\frac{X_3}{X_2},$$

and consequently

$$\frac{dx_3}{dx_1} \div \frac{dx_3}{dx_2} = \frac{X_2}{X_1},$$

where x_2, x_1 are functions of x_2, x_1 respectively: hence taking the logarithm and differentiating successively with regard to x_1 and x_2 we have

$$\frac{d}{dx_1}\frac{d}{dx_2} \log \left(\frac{dx_3}{dx_1} \div \frac{dx_3}{dx_2}\right) = 0,$$

which is the required partial differential equation of the third order.

This differential equation has a simple geometrical signification. Consider three consecutive positions of the line meeting the cubic curve in the points 1, 2, 3; 1′, 2′, 3′; 1″, 2″, 3″ respectively: *quà* equation of the third order, the equation should in effect determine 3″ by means of the other points. And, in fact, the three positions of the line constitute a cubic curve; the nine points are thus the intersections of two cubic curves, or, say, they are an 'ennead' of points; and any eight of the points thus determine uniquely the ninth point.

---

10. *On the Differential Equations satisfied by the Modular Equations.* *By* Professor H. J. S. Smith, *M.A., F.R.S.*

---

11. *On the q-Series in Elliptic Functions.* *By* J. W. L. Glaisher, *M.A., F.R.S.*

---

12. *On the Elucidation of a Question in Kinematics by the aid of Non-Euclidian Space.* *By* Robert S. Ball, *LL.D., F.R.S.*

It is well known that the family of quadric surfaces denoted by the equation—

$$(a-k)\,x^2 + (b-k)\,y^2 + (c-k)\,z^2 + (a-k)\,(b-k)\,(c-k) = 0$$

denotes the screws about which a body with freedom of the third order can twist. The parameter k is the pitch.

It is easily shown that this family of surfaces is inscribed in a common tetrahedron of which the faces are the imaginary planes denoted by—

$$\sqrt{b-c}\,x + \sqrt{c-a}\,y + \sqrt{a-b}\,z + \sqrt{b-c}\,\sqrt{c-a}\,\sqrt{a-b} = 0$$

and the three other expressions which can be produced by the indeterminateness of the signs of the radicals.

Each of these surfaces also passes through the four points in which the two cones—

$$x^2 + y^2 + z^2 + 0$$
$$ax^2 + by^2 + cz^2 = 0$$

are cut by the plane at infinity. These points lie one by one on each of the four faces of the tetrahedron.

It occurred to me that these properties of the system of surfaces were probably only the 'survivals' of a more interesting geometrical system in non-euclidian space. These anticipations have been fulfilled, and the result is to give a complete geometrical theory of the statics and kinematics of a rigid body with three degrees of freedom in non-euclidian space.

The most general motion of a body is produced by rotations around a pair of lines which are conjugate polars with regard to the absolute. For convenience I denote these rotations by $\omega \cos a$ and $\omega \sin a$. The total amplitude of the motion is ω, while its pitch is denoted by a. A pair of conjugate polars with their associated a form in non-euclidian space the analogous conception to a screw in ordinary space.

The first step in the theory is to find the condition that a twist about one screw shall do no work against a wrench on another screw.

Let A and A′ be the conjugate polars forming the first screw whose pitch is a, and let B and B′ be the conjugate polars of the second with the pitch β. A pair of common transversals can be drawn across the four lines A A′ B B′; these are the common perpendiculars to A and B; let their lengths be x and y.

Then the condition of which we are in search is,

$$\cos x \cos y \sin (\alpha+\beta)-\sin x \sin y \cos (\alpha-\beta)=0.$$

If a system has freedom of the third order, there must be a doubly infinite system of screws about which it can twist; among these let us take three of pitches α, viz. A, A′ and B, B′, and C C′. Draw a transversal X across A, B, C, then x' will intersect A′, B′, C′. Attribute to x a pitch $-\alpha$, then x will be neutral to A, B, C. Similarly y and z may be drawn across A, B, C. It is obvious that any screw neutral to x, y, z, must belong to the required three-system. Hence it follows that all the generators of the hyperboloid A B C, and of the same system as A, B, C, must belong to the three-system, and thus we have the result that—

All the screws of given pitch belonging to a three-system lie on two quadrics which are reciprocal polars with regard to the absolute. Each screw is made up of a generator on one quadric, and its conjugate polar on the other.

Draw a common tangent plane to the absolute, and the two reciprocal quadrics S and S′. Let T be the point in which this plane meets the absolute. It is obvious T must lie on S and S , and that two rays through T in the tangent plane must be a pair of conjugate polars forming a screw with the given pitch. Let T L and T M be the two generators of the absolute through T, then any pair of lines through T which formed an harmonic pencil with T L and T M would be a pair of conjugate polars. The pitch of the screw of the system whose conjugate polars pass through T is therefore ambiguous, and consequently every different pair of hyperboloids for each different pitch must touch this tangent plane and pass through M, T.

As there can be eight tangent planes to the absolute and a pair of reciprocal quadrics, so it follows that every pair of quadrics must touch these planes and pass through the eight points of contact. We thus have the one degree of freedom left to the quadrics corresponding to the different varieties of pitch. In ordinary space these planes reduce to the four already mentioned.

---

13. *On a Theorem relating to the Description of Areas. By* William Woolsey Johnson, *Professor of Mathematics in the Naval Academy, Annapolis, U.S.*

Let a straight line AB move in any manner in a plane, and let ρ_1 and ρ_2 represent the distances of the extremities A and B from the point about which the line is for the instant rotating; then, ϕ denoting the line's inclination to any fixed line, the area swept over by the line is denoted by

$$\tfrac{1}{2}\int(\rho_2^2-\rho_1^2)\,d\phi=\int\frac{\rho_2+\rho_1}{2}(\rho_2-\rho_1)\,d\phi.$$

In this expression the direction AB is regarded as the positive direction, and thus an area which passes from the left to the right side of AB is positively generated, while an area which passes from the right to the left side of AB is negatively generated. It is easily seen that, with this interpretation, the expression represents the area swept over by AB whatever be the signs of ρ_2 and ρ_1 ; and consequently if l denotes the length of AB and ρ_m the distance of its middle point from the centre of rotation at the instant, the expression for the area is

$$\int l\rho_m\,d\phi.$$

Now let A and B describe two closed curves (whose areas may be denoted by A and B) returning simultaneously to their original position; and let the perimeters of these curves be described in the positive direction. Then every point in the area A, and not in the area B, will pass at least once from left to right under the line AB, and in all cases once more in that direction than in the opposite direction.

Hence the area included in A and not in B will be positively generated. In like manner the area included in B and not in A will be negatively generated, while the area common to A and B, or exterior to A and B, will disappear from the integral. We therefore have

$$B - A = \int l\rho_m \, d\phi,$$

in which the area B or A is to be regarded as negative if its perimeter is described in the negative direction. When BA is a line of fixed length, let $l = 2b$, then

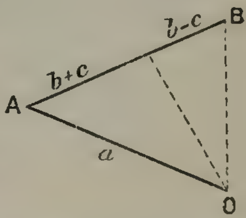
$$B - A = 2b \int \rho_m \, d\phi \quad . \quad . \quad . \quad . \quad (1).$$

2. This theorem may be employed in the explanation of Amsler's Planimeter; for let $OA = a$ be the bar which rotates about the fixed point O, and let $AB = 2b$ be the bar carrying the recording wheel, situated, say, at the distance c from its middle point (see figure). Then, s denoting the distance recorded by the wheel when B describes the perimeter of a closed curve,

$$s = \int (\rho \;\; + c) \, d\phi = \int \rho_m \, d\phi + 2k\pi c,$$

in which k denotes the number of revolutions made by the bar AB. Hence from (1)

$$B - A = 2bs - 4k\pi bc.$$



In the use of the instrument two cases arise. First, O may be exterior to the area B; in this case $k = 0$, and since the point A reciprocates over an arc of a circle, $A = 0$, and we have

$$B = 2bs.$$

Secondly, O may be within the area B, in which case $A = \pi a^2$ and $k = 1$, hence

$$B = 2bs + \pi(a^2 - 4bc).$$

The constant which is added to $2bs$ in this case is the area of the circle whose radius is OB, when the instrument is in such a position that the line joining O with the wheel is perpendicular to AB; for $OB^2 = a^2 - (b+c)^2 + (b-c)^2$; and this should be the case, for if B describe this circle s is evidently $= 0$.

3. The theorem (1) may be employed also to express the area described by any point of the line AB in terms of the areas of A and B. Thus, if s denotes the distance recorded by a wheel situated at the middle point of AB,

$$B - A = 2bs \quad . \quad . \quad . \quad . \quad . \quad (2).$$

Let C be a point at a distance c from the middle point of AB. The length of AC is $b + c$, and the distance of its middle point from the middle point of AB is $-\frac{1}{2}(b - c)$; therefore the distance recorded by a wheel situated at the former point would be

$$s' = s - k\pi(b - c),$$

(k denoting as before the number of revolutions of AB), and we have

$$C - A = (b + c)\, s' = (b + c)\, s - k\pi\, (b^2 - c^2) \quad . \quad . \quad (3).$$

Eliminating s by means of (2),

$$C = \frac{b-c}{2b} A + \frac{b+c}{2b} B - k\pi\, (b^2 - c^2) \quad . \quad . \quad . \quad (4),$$

or, if $2b = l$ and $\frac{b+c}{b-c} = \frac{m}{n}$, we have for the area described by the point which cuts AB in the ratio $m : n$

$$C = \frac{nA + mB}{m + n} - \frac{kmn}{(m+n)^2} \pi\, l^2.$$

As a special case of (4), if C is the middle point of AB and describes a circle whose radius is a, while AB revolves uniformly, the areas A and B will be equal epitrochoids, and (4) becomes

$$C=\pi a^2=A-k\pi b^2,$$

whence

$$A=\pi\,(a^2+kb^2),$$

in which a is the sum of the radii of the fixed and rolling circles, b is the distance of the generating point from the centre of the rolling circle, and $k-1$ is the number of the branches of the epitrochoid.

---

14. *On the Equation of the Multiplier in the Theory of Elliptic Transformation. By* Professor H. J. S. Smith, *M.A., F.R.S.*

---

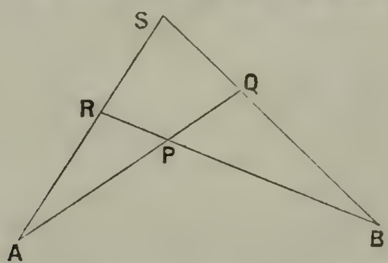
15. *On a Linear relation between two Quadratic Surds. By* Professor H. J. S. Smith, *M.A., F.R.S.*

---

16. *On a Class of Binodal Quartics. By* Professor R. W. Genese, *M.A.*

If A B be third diagonal of a quadrilateral Q, then *any* quartic with nodes at A, B, and circumscribing Q, has the following properties:—

1°. If P be any point on the curve, and A P, B P meet the curve again at Q, R, then B Q, A R intersect on the curve; or, we may state it thus, if A P Q be any



secant, and B P, B Q meet the curve again in R, S, then R S passes through A.

2°. If A P Q turn round A, then B P, B Q belong to a fixed involution.

The equation to the curve in biangular co-ordinates is

$$(a_1x^2+b_1x+c_1)y^2+(a_2x^2+b_2x+c_2)y+(a_3x^2+b_3x+c_3)=0$$

With the condition

$$\begin{vmatrix} a_1, & b_1, & c_1 \\ a_2, & b_2, & c_2 \\ a_3, & b_3, & c_3 \end{vmatrix}=0.$$

SATURDAY, SEPTEMBER 3.

The following Papers were read:—

1. *On a Class of Differential Equations. By* Professor Halphen.

---

2. *On the Aspects of Points in a Plane. By* Professor Halphen.

---

3. *On a Connection between Homographies in a Straight Line and Points in a Space. By* Cyparissos Stephanos.

4. *On Involutional* (1 1) *Correspondence.* *By* Professor GENESE, *M.A.*

It is here proposed to say that there is an involutional (1, 1) correspondence between two points whose co-ordinates (say, areal) are $x:y:z$, $\alpha:\beta:\gamma$ when if

$$x:y:z::f_1(\alpha,\beta,\gamma):f_2(\alpha,\beta,\gamma):f_3(\alpha,\beta,\gamma),$$

then

$$\alpha:\beta:\gamma::f_1(x,y,z):f_2(x,y,z):f_3(x,y,z).$$

f_1, f_2, f_3 denoting three distinct homogeneous functions.

The following method gives five solutions of the problem suggested. Consider the equations

$$\frac{F_1(x,y,z)}{F_1(\alpha,\beta,\gamma)}=\frac{F_2(x,y,z)}{F_2(\alpha,\beta,\gamma)}\quad\ldots\quad(1)$$

$$\frac{F_3(x,y,z)}{F_3(\alpha,\beta,\gamma)}=\frac{F_4(x,y,z)}{F_4(\alpha,\beta,\gamma)}\quad\ldots\quad(2)$$

It is clear that $x:y:z::\alpha:\beta:\gamma$ is one solution. If then F_1, F_2, F_3, F_4 be so chosen that (1) and (2) admit of *only one other* common solution *containing* α, β, γ that solution will by symmetry determine an involutional (1, 1) correspondence.

Let C^m, C^n denote the loci represented by

$$F_1(x,y,z)=\gamma F_2(x,y,z)\quad\ldots\quad(3)$$

$$F_3(x,y,z)=\mu F_4(x,y,z)\quad\ldots\quad(4)$$

of the mth and nth degrees respectively.

Then, γ, μ being chosen to make C^m C^n intersect at α, β, γ, we have the curves (1), (2).

Now C^m, C^n intersect in mn points; for the solution of our problem $p=mn-2$ of these must be fixed points. Also C^m, C^n pass through m^2 and n^2 fixed points respectively: C^m is determined by $\frac{m(m+3)}{2}$ points, &c.

Five solutions are obtained:—

$$\left.\begin{array}{l} n=1,\ m=2,\ p=0 \\ n=1,\ m=3,\ p=1 \\ n=2,\ m=3,\ p=4 \end{array}\right\}\ \begin{array}{l}\ldots A_1\\ \ldots A_2\\ \ldots A_3\end{array}$$

$$\left.\begin{array}{l} n=2,\ m=2,\ p=2 \\ n=3,\ m=3,\ p=7 \end{array}\right\}\ \begin{array}{l}\ldots B_1\\ \ldots B_2\end{array}$$

Interpretations

A_1. $F_1=0, F_2=0$ any two conics $F_3=0, F_4=0$ any two straight lines (not intersecting in a point common to $F_1=0, F_2=0$)

A_2. $F_3=0, F_4=0$ any two straight lines $F_1=0, F_2=0$ two cubics passing through the intersection of $F_1=0, F_2=0$

A_3. $F_3=0, F_4=0$ any two conics $F_1=0, F_2=0$, two cubics passing through the points common to $F_3=0, F_4=0$.

B_1. $F_1=0, F_2=0, F_3=0, F_4=0$ represent conics; but two of the points of intersection of $F_1=0, F_2=0$ must coincide with two on $F_3=0, F_4=0$.

B_2. $F_1=0, F_2=0, F_3=0, F_4=0$ represent cubics having seven points common.

Note 1.

If, having obtained a correspondence, we put therein $x:y:z::\alpha:\beta:\gamma$, we obtain the locus of points at which the lines (1), (2) touch.

Note 2.

The analysis of A_1 *suggested* the following algebraical exercise:—

$$\text{If } \frac{x}{\alpha}=\frac{y}{\beta}=\frac{z}{\gamma}=\frac{f_{n+1}(\alpha,\beta,\gamma)+f_n(\alpha,\beta,\gamma)}{f_{n+2}(\alpha,\beta,\gamma)-f_{n+1}(\alpha,\beta,\gamma)}$$

where f_n, f_{n+1}, f_{n+2} are any homogeneous functions of $n, n+1, n+2$ dimensions respectively; then will

$$\frac{\alpha}{x}=\frac{\beta}{y}=\frac{\gamma}{z}=\frac{f_{n+1}(x,y,z)+f_n(x,y,z)}{f_{n+2}(x,y,z)-f_{n+1}(x,y,z)}$$

5. *On the Velocity Function of a Liquid due to the Motion of Cylinders and Surfaces of Revolution.* By A. G. GREENHILL.

MONDAY, SEPTEMBER 5.

The following Reports and Papers were read:—

PHYSICAL DEPARTMENT.

1. *Report of the Committee on Meteoric Dust.*—See Reports, p. 88.

---

2. *Report of the Committee on Tidal Observations in the English Channel and the North Sea.*—See Reports, p. 160.

---

3. *Report of the Committee on Underground Temperature.* See Reports, p. 90.

---

4. *Report of the Committee on the Calculation of Sun-heat Coefficients.* See Reports, p. 89.

---

5. *Observations of Atmospheric Electricity at the Kew Observatory during* 1880. *By* G. M. WHIPPLE, *B.Sc., F.R.A.S.*—See Reports, p. 443.

---

6. *On a Universal Sunshine Recorder Stand.* *By* G. M. WHIPPLE, *B.Sc., F.R.A.S.*

A description was given of a new form of card-supporter for the Campbell Sunshine Recorder, constructed by Mr. L. P. Casella at the suggestion of the author and exhibited to the Section. It consists of a light frame capable of holding the slip of cardboard to be burned by the sun in any desired position. It is arranged so as to receive ordinary parallel strips of card at all times of the year, and to allow of the instrument being employed on any part of the earth's surface without detriment to its efficiency.

The card-holders themselves are movable, so as to permit of the cards being changed indoors or dried if wet, before removal, thereby avoiding tearing or mutilation of the record in the operation. The instrument is also furnished with appliances for placing the card correctly in position to receive the sun's image.

---

7. *On the Calibration of Mercurial Thermometers by Bessel's Method.* *By* Professors T. E. THORPE, *Ph.D., F.R.S., and* A. W. RÜCKER, *M.A.*

The authors have recently had occasion to calibrate with great care a number of mercurial thermometers.

The method adopted was Bessel's, as modified by Arthur von Œttingen ('Ueber die Correction der Thermometer,' A. von Œttingen. Dorpat, 1865.)

In this there appear to be two weak points, viz., (1) the concentration of the observations on the central part of the scale, (2) the uncertainty as to the best method of uniting the two curves obtained respectively from the 'Hauptpunkte,' and the other points at which observations are made. These were in part strengthened by introducing the additional measures (used by Arthur von Œttingen in the second approximation only) in the first approximation and by giving to the 'Hauptpunkte' a higher relative value than is assigned to them by von Œttingen. Under these conditions the method, though very laborious, is capable of giving excellent results.

Thus in the case of six thermometers, on three of which the measurements necessary for the calibrations were made at Kew, and on three at the Owens College, by Messrs. G. Baker and M. Hirakoa respectively, the difference between any one measurement of the length of a mercurial thread expressed in terms of the corrected scale and the mean length of that thread equals or exceeds 0·01° C. (*i.e.* about 0·1 m.m.) in eleven only out of a total of 880 measurements.

The Kew thermometers had been calibrated, as is usual at that observatory, by Welsh's method ('Rep. Brit. Ass.,' 1853, p. 34). Mr. G. Baker afterwards made, in accordance with the author's instructions, the measurements necessary for the application of Bessel's method, the calculation being undertaken by the authors.

It was a matter of some interest to determine in this case the magnitude of the errors of the original calibration.

Welsh's method is undoubtedly open to the objection that the errors are additive and Von Œttingen (*loc. cit.* p. 49) seems to consider that it must always be necessary, for accurate work, to correct further a thermometer calibrated by it.

The three thermometers were numbered 561-2-3, they read from 11·5° to 29° C., from 19·5° to 68°, and from 51° to 107° respectively. The average lengths of a degree were 12·9 m.m., 11·2 m.m., and 9·5 m.m. respectively. The application of Bessel's method to the first was made by 110 measurements of the mercurial threads, to the second by 163, and to the third by 185.

The original calibration was so accurate that the second approximation of Bessel's method was unnecessary in two cases, and was only partly carried out in the third.

The maximum positive and negative corrections were in the case of

Th.	561	+0·004° C.	and	−0·004° C.
„	562	+0·012°	„	−0·005°
„	563	+0·008°	„	−0·011°

As will be seen from the above description of the thermometers, the larger of these quantities are about equal to the limit of certainty in reading.

In no case would the calibration error in the determination of a difference of temperature have amounted to 0·02° C. It may therefore be concluded that Welsh's method, as applied at Kew to selected tubes, and with a measuring instrument of great accuracy, is capable of giving first-rate results. The errors which remain when it has been applied are so small that they may be neglected in all cases but those where the thermometers are to be used under the most favourable conditions, *i.e.* with the stem at the same temperature as the bulb, &c.

This satisfactory conclusion is confirmed by the fact that Professor Rowland has recently stated that the calibration of the Kew thermometer used by him in his research on the Mechanical Equivalent of Heat was practically perfect.

---

8. *On the General Coincidence between Sun-spot Activity and Terrestrial Magnetic Disturbance. By the* Rev. F. Howlett, *F.R.A.S.*

The object of this paper was to inquire how far solar activity, more especially as regards sun-spots, is wont to be accompanied by terrestrial magnetic disturbances, as recorded by the automatic magnetic declination curves at Kew and Greenwich.

The data for such an investigation were furnished by comparisons instituted between the more striking instances of sun-spots gathered out of a long series of solar observations carried on by Mr. Howlett from 1859 to the present epoch, and the synchronous conditions of the magnetic curves at the observatories above mentioned. The telescopic drawings of the spots were obtained with an achromatic of three inches' aperture, by Dollond, and of forty-eight inches' focal distance, projecting the sun's image on a large white screen in a darkened chamber.

By employing a Huygenian eyepiece magnifying 120 linear, and placing the screen at the distance of five feet, two inches from the eyepiece, a beautiful image of the sun was obtained, five feet four inches in diameter, and of which every inch corresponded to just 30″ of the celestial arc.

Not only were the measurements of all the solar phenomena rendered thereby exceedingly easy, but the conditions of amplification, illumination, and definition of details were combined in about the best possible manner for the observer's purpose, which was to maintain an accurate record of the solar spots, and very frequently of the faculæ also, on a large scale; these have been collected into five volumes, and presented to the Royal Astronomical Society.

The comparisons commence with the very remarkable and cyclonic group of August and September, 1859, which was uniquely distinguished (so far as observations have hitherto gone) by the remarkable outburst of intense white light, far brighter than the photosphere itself, which fortunately was witnessed on the forenoon of September 1, by the late Messrs. Carrington and Hodgson, but which Mr. Howlett missed seeing by only a few minutes, having completed his drawings, and so left the telescope.

Other striking and, if they may be so termed, crucial groups, were compared with the magnetic records—very notably the great spot of October, 1865, engravings of which may be found in the volume of the 'Proceedings of the Royal Astronomical Society' for the year last mentioned; as also the prodigious groups of February, 1870, which were observed and drawn on the occasion of their reappearance, by revolution, in the three consecutive months of February, March, and April of that year; and on the last of which months the total displacement, at one and the same time, of the solar photosphere—or, in other words, the total area occupied by the sun-spots—was no less than 5,000,200,000,000 square miles, or about twenty-seven times that of the superficies of the earth!

So again, in August and September, 1870, immense groups, occupying from 4,000,000,000 to 5,000,000,000 square miles, were observed to make two consecutive revolutions—[on the latter of which two occasions a beautifully enlarged photograph of the sun, twenty-four inches in diameter, was made by Mr. Titterton, of Ely, under the auspices of the late Canon Selwyn, and was exhibited to Section A.] On all these occasions great magnetic disturbances, amounting often to absolute magnetic storms, were unequivocally manifested; and, in fact, out of twenty-four comparisons instituted, the following is the summary of results; as showing the coincidence of extensive solar activity and synchronous magnetic disturbance:—

Intensely	5	21 affirmative
Very decidedly	3	
Decidedly	9	
Moderately	3	
Negatively, no spots, no storms during the year 1879	1	
Questionable	1	3 negative
Contradictory	2	
		24

Thus, then, from the data collected, it would certainly appear that, not only on the occasion of large groups of spots occurring at the periods of maximum, but also often on the occasion of any other marked outbursts of spots, there will generally be found to be a corresponding amount of terrestrial magnetic disturbance. But still, from an impartial and careful comparison of the data appealed to, it is clear that the magnetic disturbances were manifested in a variety of ways, not only as regards the extent—for instance, of the excursions of the needle, the rapidity of the oscillations, or the persistency of the more moderate disturbances,—but also the varying intervals of time at which the disturbances take place, after the commencement of the observed solar outbursts.

With respect, lastly, to other reactionary influences, the Director of the Kew Observatory states that, on the occasion of the perihelion passage of the Comet *b*, 1881, on the 16th day of June last, the terrestrial magnetic curves were unusually quiescent.

---

9. *On Magnetic Disturbances and Earth-currents. By* Professor W. Grylls Adams, *F.R.S.*—See Reports, p. 463.

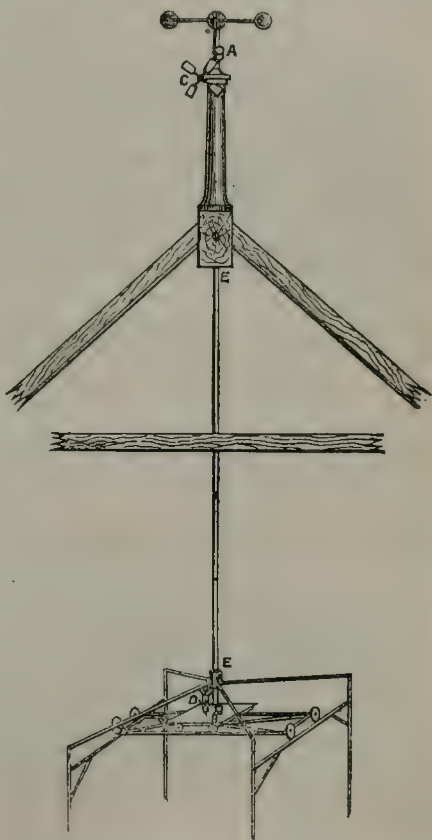
10. *On the Arrestation of Infusorial Life by Solar Light. By* Professor JOHN TYNDALL, *F.R.S.*—See Reports, p. 450.

---

11. *On a new Integrating Anemometer. By the* Rev. J. M. WILSON, *M.A., and* H. S. HELE SHAW.

The primary object of this instrument is to obtain a record of the total transference of air over any given spot, in order to be able to arrive at a determination of the circulation of air on the globe, in a similar way to that in which the circulation of the water is known to take place. Few results would be so interesting as a map of the world showing the simultaneously existing air-currents, so as to enable the average circulation of the whole to be seen at a glance. The existing anemometers only give the resultant after considerable labour in calculation, by taking the average direction and velocity for short periods, first by resolving the various components, then summing and recombining them. The tedious and inaccurate nature of this process is obvious. Mr. Wilson, therefore, conceived the idea of having a pencil moved over a board in the direction of, and with a velocity proportional to that of, the wind, and submitted a sketch of a plan based upon this idea to Mr. Shaw, who has undertaken the complete design and superintended the construction of the first instrument, which, however, must be considered rather in the light of an experimental one. The ordinary cup-anemometer of Robinson is used to drive a train of wheels by means of a central spindle on which is a worm—and thus ultimately to turn, at a much reduced speed, a serrated roller, which gives motion to a horizontal table, and on this is laid the sheet of paper. The plane of rotation of the roller is always kept coincident with the direction of the wind, by having its bearings in a hollow rod which contains the central one, and which only turns as the wind changes its direction; thus the curve is identical in direction with the wind. The board and paper are protected by a sloping wooden roof, which supports a pillar five feet high, carrying the cups and direction-vanes. The original plan was to have the board, which is two feet square, moving on truly spherical steel balls, upon a marble slab four feet square. The much better arrangement is now used of a pair of light wrought-iron frames, moving by means of flanged rollers in directions at right angles to each other, the upper on the lower, and the lower on the marble, kept parallel by having rollers running in the frame which supports the roof. By this means a movement can be obtained in any direction whatever without any rotation being able to take place, and the results obtained during the few days in which the instrument in its completed form has been at work are very satisfactory. Fig. 2 shows the curves obtained from August 30 to September 3, combined so as to give at a glance the direction and volume of wind passing over University College, Bristol, during that time. The trace of the

FIG. 1.

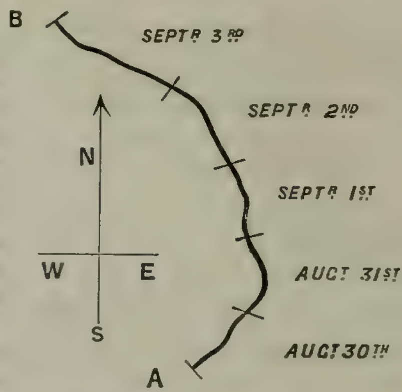


INTEGRATING ANEMOMETER.
(N.B. D is fastened to and supported by the frame, and *not* to the vertical spindle.)

curve commenced at A and ended at B, and though the rough diagram cannot pretend to great accuracy, it shows clearly how the wind veered from the N.E. to the N.W., and the only alterations that are required are in matters of detail.

Mr. Shaw proposes to apply clockwork in a very inexpensive way, so as to cause marks to be made along the curve at regular intervals of time, and by the introduction of this element, it is evident that the velocity will be given. The total length of the curve is a convenient measure of the wind-power at the spot: the marks will show the velocity at any time, and the *resultant* length of the curve gives the direction and amount of the transference of air at the spot. The general view of the instrument as it will be applied to observatories is shown in Fig. 1. Here it will be observed the train (A) for reducing the velocity of the cup's spindle is placed at the top of the rod instead of the bottom, where it is now situated, and thus the length becomes a matter of small importance, since the slow motion of the spindle which conveys motion to the serrated roller at (B), will ensure the reduction of the friction to a minimum; similarly the adoption of the self-acting head at (C) (the velocity ratio of whose train is 1000) will cause the vertical tube (E, E,) in which is contained the cup's spindle to turn with almost the lightest winds—finally the clockwork for recording intervals of time is placed at (D).

FIG. 2.



---

12. *On the Isothermals of the British Isles.* *By* ALEX. BUCHAN, *M.A., F.R.S.E.*

---

13. *On the Diurnal Period of Hailstorms.* *By* ALEX. BUCHAN, *M.A., F.R.S.E.*

---

14. *On the Sunspot Period, and Planetary Tides in the Solar Atmosphere.* *By* F. B. EDMONDS.

The author directs attention to a development of the planetary hypothesis of solar disturbance. The tidal disturbing effect of the planets on the sun, acting at their mean distances, will be in accordance with the following order: Jupiter Venus, Mercury, Earth, Saturn, Mars, Uranus, Neptune. The first four of these are the most influential, and offer six combinations in pairs. Any one of these pairs may be taken with a third planet. Taking Jupiter as the third planet, the author considered the combination involving Venus and the Earth, and gave some of the results already obtained, but reserved the remaining combinations for notice on a future occasion.

---

15. *Some Laws which regulate the Succession of Mean Temperature and Rainfall in the Climate of London.* *By* H. COURTENAY FOX, *M.R.C.S.*

---

16. *On the Blowing Wells near Northallerton.* *By* THOMAS FAIRLEY, *F.R.S.E.*

In 1878, Mr. Hutton of Solberge, near Northallerton ($3\frac{1}{2}$ miles S.), informed me of a remarkable outflow of gas from a well situated on his estate near his residence. This current was observed while the barometer was falling. A chemical analysis of this gas showed it to be common air containing 20·9 per cent.

of oxygen. Conceiving that there must be a large underground cavity communicating with the shaft of the well, I thought the phenomena worthy of investigation, and through Mr. Hutton's kindness and assistance I was able to make these experiments.

The out-currents were very powerful and attracted the attention of everyone in the neighbourhood, and equally powerful in-currents were observed during the periods of a rising barometer. On descending the shaft of the well 15 yards, the fissures in the sandstone were observed where these currents passed. Analyses were made of the sandstone and the water in the well. I then attempted, by careful readings of the barometer at Solberge, and measurement of the currents, to obtain, by the application of Boyle's law, the approximate volume of the cavity. The readings of the instruments were made by Mr. Hutton.

Experiments were made, first with a Biram's vane anemometer; afterwards with very large dry gas-meters. Only those observations could be used where the barometric change continued so long that the current produced had time to exhaust itself. The temperatures of the out-currents and of the air were also noted. In cold weather the out-current was warmer than the outside air.

The anemometer observations were made in July and in December 1879. Of these, two sets of observations made in July, and two made in December, give an average result of 10·3 millions of cubic feet as the approximate volume of the cavity.

The dry gas-meter observations were made in March and April 1880, with two meters kindly lent by Messrs. Glover & Son, of London, capable of passing about 3,000 cubic feet per hour.[1] Even this capacity was insufficient, and the experiments were stopped by the meters being thrown out of gear by the force and rapidity of the current. One set of observations were, however, tolerably perfect and complete, and give a capacity of ten millions of cubic feet very nearly. These volumes correspond to a cubic space of about 217 feet.

Caverns are generally found in limestone rocks. Geologists consider that the magnesian limestone would be here about 400 feet below the surface. The nearest exposed section is, however, at some distance.

Another blowing well is located at Langton Hall, 5 miles N.W. from Solberge, both being located on the rising ground separating the valleys of the rivers Wiske and Swale. In this case also the currents consist of air, and their direction and volume depend on the changes of the barometer.

Of course the measurements mentioned above cannot give more than a minimum volume for the cavity, if there are any other openings.

The third blowing well I have not yet visited. It is situated on the estate of Mr. Paver Crow at Ornhams, 2 miles south from Boroughbridge. I have analysed the water, which is somewhat similar to that of the water at Solberge. The currents here are very powerful, causing a rushing noise in passing through the fissures.

In all these cases the currents are extremely sensitive to the changes of the barometer. I have examined and inquired about other wells in the district, but these are the only blowing wells I have found. Other wells near Solberge, within a mile of the blowing well, gave no currents.

---

17. *Some Remarks on Artificial Flight.*

By FRED. W. BREAREY, *Hon. Secretary of the Aeronautical Society.*

The author examined the various fallacies which have been entertained in ancient and modern times with respect to the flight of birds, and explained some of his own experiments during the last six years. With respect to the hollow bones of birds, and the opinion of many that such an arrangement is intended as a receptacle for a rarefied gas, he quoted a remark by the author of a paper read by a member of the Aeronautical Society, that if the whole body of the bird were filled with the lightest gas or even so much vacuous space, the supporting effect

[1] They were coupled, so that one registered the in-, the other the out-current.

would be of the slightest value; for supposing that a bird of 2 lbs. weight displaces $\frac{1}{12}$ of a cubic foot of air, or about 46 grains in weight only, the buoyancy imparted to it would really amount to but $\frac{1}{3}$ of 1 per cent. of the weight of the bird. Besides which the force imparted to the wing of the bird is due to its *weight* only, and were it as light as an equal bulk of air it could not fly at all. The author next alluded to the upward stroke of the wing, and the theory that in it the feathers separate so as to allow of the air passing through. There is really no necessity for such action, because although the wing be rising in order to repeat the downward stroke, it is all the time pressing against the air with the whole weight of the bird's body, and in that act of rising the wing has also a propelling effect.

He then proceeds to argue that the weight of the bird plays an active part in its flight, and that this result arises from the action of that portion of the pectoral muscle which depresses the wing. So great is the tension of this muscle that it is highly probable that, in the case of those long-winged and heavy birds which are able to fly without apparently moving a feather, the wings are kept extended against the resistance of the air underneath without any voluntary effort of the bird. Its weight pressing upon the air causes this muscle to expand in raising the wing, and aids in the effect of the downward stroke by its contraction. The author exhibited a model with wings 4 feet from tip to tip and 3 feet 2 inches from head to tail. The wings are actuated by M. Renaud's plan of strands of india-rubber previously put into a state of tension, which in unwinding create a flapping of the wings. By an india-rubber cord attached to the under part of the wing and passing under the shaft to which the mechanism is attached, an equilibrium between the two forces is attained; that is to say, the india-rubber strands are wound up to that extent that the wings in rising stretch the india-rubber cord—or, as the author calls it, the pectoral cord—until one force neutralises the other; so that, held in the hand, there is no action. When liberated, and committed to the pressure of the air underneath the wings, the weight of the model causes the wings to be elevated, and therefore stretches the pectoral cord, which in its contraction assists the power derived from the twisted rubber in depressing the wings against the weight of the model. During this action the flight is deliberate and well-sustained for 40 feet or more.

As, over and above this condition of equilibrium, there is plenty of reserve power, the flight of the model is capable of great extension.

The author argues from this that the power required to produce flight has been much exaggerated, and that weight is an absolute necessity. He shows various forms of flight, but he believes that there can be nothing superior to the reciprocating wing-action which propels and supports at the same time. He recommends, however, trial of an apparatus which, from his experiments, promises success. Is it possible, he asks, to control some arrangement in the nature of a parachute by altering its form and making it longitudinal—giving it, in fact, a head and a tail. Such an apparatus, made by himself, was liberated from a balloon which rose from Woolwich Arsenal, and it travelled back, by the aid of gravity alone, to the Arsenal—of course against the breeze which wafted away the balloon —a distance of half a mile.

He argues from this that if the fabric can be manipulated so that propulsion also can be imparted to it, then some encouraging results would be likely to follow. He showed a model of large size upon this principle, and how, by the action of the wing-arms, a wave is transmitted from head to tail along a loose surface in shape like a kite. This loose surface necessarily requires a fall before it can be inflated by the air underneath. The wave-motion is then found adequate to its propulsion. An estimate of the power required to propel and support 100 lbs. weight in the air has been made from the data given from this model, which weighs with added lead $2\frac{1}{2}$ lbs., and it is believed that $\frac{1}{3}$ h.p. will be required for each 100 lbs.

Having arranged about 300 square feet of a suitable fabric, the author proposes that, to effect a start, the apparatus, having a flat-bottomed carriage, shall be placed upon a wheeled platform or truck, the two front being higher than the hind wheels, so that upon running down the side of a hill upon a tramway the apparatus shall preserve a horizontal position. That, being weighted to ascertain the balance, which can only be effected by repeated trial, the truck be liberated. The effect will be to inflate the fabric into a parachute—to elevate the wing-arms and stretch the pectoral cord, and if properly balanced the machine will descend safely in the direction of its head.

If it be found that a weight equal to that of a man can be brought to the ground safely, then might come the manual test, and his capacity to depress the wing-arms so as to keep up an undulation.

---

18. *On the desirability of observing Occultation of Stars, of the first and other bright magnitudes, from places where they are to be seen near the horizon. By* H. S. Williams, *M.A., F.R.A.S.*

MATHEMATICAL DEPARTMENT.

1. *Sur la représentation des rotations autour d'un point par des points de l'espace. By* Cyparissos Stephanos.

---

2. *On the Polar Planes of a point with respect to four Quadric Surfaces. By* W. Spottiswoode, *M.A., Pres. R.S.*

---

3. *On the Extension of the Theory of Screws to the Dynamics of any material system. By* Robert S. Ball, *LL.D., F.R.S., Royal Astronomer of Ireland.*

A mechanical system of any number of rigid pieces, anyhow connected, is displaced to an indefinitely close position. This displacement could have been produced by giving to each piece a twist of definite amplitude about a given screw. We thus have a series of *primary* screws equal in number to the pieces of the system. If the twists on any two consecutive screws be compounded they will form a twist on a third screw, which we may speak of as being *intermediate.* The whole series of screws primary and intermediate is called a *screw-chain* and, combined with a single amplitude or metric element, expresses a displacement of the system.

If the system have but one degree of freedom, then the only possible movements are those of twisting on one screw-chain. If the system be capable of displacement about a second screw-chain it must necessarily be capable of displacement about a singly infinite number of other chains, which can be simply constructed, when a third chain has been found. The result of the first twist and the second twist could have been directly obtained by a third twist. We thus have three screws corresponding to each element. These sets of three are each co-cylindroidal. We thus have a number of cylindroids equal to the number of elements of the system. To find another screw-chain about which the system can twist, select any screw on one of the cylindroids, and a homographic screw on each of the others; this will give the primary screws. Each set of three intermediate screws are also co-cylindroidal, and the required intermediate screws are also a homographic system.

In the case of a system capable of twisting about three arbitrary screw-chains, it can be shown that the determination of subsequent chains can be obtained by the aid of point homographies in planes. With freedom of the fourth order the point homographies of spaces may be used. For higher orders of freedom conceptions analogous to those of 'Parallel Projections' in statics are available.

The most general set of forces acting upon a system can also be represented by a series of wrenches on the screws of a screw-chain. The screw-chain is thus symmetrically related to the most general group of forces and to the most general form of displacement.

The theory is extensive, but one illustration may be given. If the forces act impulsively, the system commences to twist about an instantaneous screw-chain. Generally the impulsive screw-chain and the instantaneous screw-chain are different. It will, however, sometimes happen that the two coincide. The number of cases where this occurs is equal to the number of degrees of freedom which the system possesses.

---

4. *On a Property of a small Geodesic Triangle on any surface. By* Professor H. J. S. Smith, *M.A., F.R.S.*

---

5. *On the General Analogy between the formulæ of singly and doubly Periodic Functions. By* J. W. L. Glaisher, *M.A., F.R.S.*

The object of the paper is to consider the general groups of formulæ in Elliptic Functions, the existence of which is indicated by formulæ involving trigonometrical functions. As we should expect, the former are much more complete, and exhibit greater regularity, than the latter.

Change of the argument.—In Trigonometry there are six primary functions, sin u, cos u, tan u, cot u, sec u, cosec u, of which two are even and four are uneven. These six functions are divisible into three pairs, sin u and cos u, tan u and cos u, sec u and cosec u, which are such that if we select from them any triad, one being taken from each pair, the other three functions may be derived from them by a change in the argument, that is by the substitution of $\frac{1}{2}\pi + u$ for u. The number of such triads is eight, the total number of triads that can be formed from the six functions being twenty.

In Elliptic Functions there are twelve primary functions, sn u, cn u, dn u, $\frac{1}{\text{sn}\,u}$, $\frac{1}{\text{cn}\,u}$, $\frac{1}{\text{dn}\,u}$, $\frac{\text{sn}\,u}{\text{cn}\,u}$, $\frac{\text{sn}\,u}{\text{dn}\,u}$, $\frac{\text{cn}\,u}{\text{sn}\,u}$, $\frac{\text{cn}\,u}{\text{dn}\,u}$, $\frac{\text{dn}\,u}{\text{sn}\,u}$, $\frac{\text{dn}\,u}{\text{cn}\,u}$, of which six are even and six uneven. These twelve functions are divisible into three groups of four each—viz.,

$$\text{sn}\,u,\ \frac{1}{\text{sn}\,u},\ \frac{\text{dn}\,u}{\text{cn}\,u},\ \frac{\text{cn}\,u}{\text{dn}\,u},$$

$$\text{cn}\,u,\ \frac{\text{dn}\,u}{\text{sn}\,u},\ \frac{1}{\text{cn}\,u},\ \frac{\text{sn}\,u}{\text{dn}\,u},$$

$$\text{dn}\,u,\ \frac{\text{cn}\,u}{\text{sn}\,u},\ \frac{\text{sn}\,u}{\text{cn}\,u},\ \frac{1}{\text{dn}\,u},$$

which are such that if we select from them any triad, one being taken from each group, then (omitting the constant multipliers $\frac{1}{k}$, k', &c.), the other nine functions may be derived from this triad by changes in the argument, that is, by the substitution of $K+u$, $iK'+u$ and $K+iK'+u$ for u. The number of such triads is sixty-four, the total number of triads that can be formed from the twelve functions being 220. If we consider only the real substitution—viz., that of $K+u$ for u—the twelve functions are divisible into the six pairs sn u and $\frac{\text{cn}\,u}{\text{dn}\,u}$, cn u and $\frac{\text{sn}\,u}{\text{dn}\,u}$, dn u and $\frac{1}{\text{dn}\,u}$, $\frac{1}{\text{sn}\,u}$ and $\frac{\text{dn}\,u}{\text{cn}\,u}$, $\frac{1}{\text{cn}\,u}$ and $\frac{\text{dn}\,u}{\text{sn}\,u}$, $\frac{\text{sn}\,u}{\text{cn}\,u}$ and $\frac{\text{cn}\,u}{\text{sn}\,u}$ which are such that if we select from them any six functions, one being taken from each pair, the other six may be derived from them by this substitution.

Integration.—We have

$$\int \sin u\, du = -\cos u, \qquad \int \cos u\, du = \sin u,$$

$$\int \tan u\, du = -\log \cos u, \qquad \int \cot u\, du = \log \sin u,$$

$$\int \sec u\, du = \log \tan\left(\tfrac{1}{2}u + \tfrac{1}{4}\pi\right), \qquad \int \operatorname{cosec} u\, du = \log \tan \tfrac{1}{2} u.$$

four of the integrals being thus expressed as logarithmic functions. In Elliptic Functions the complete system of integrals may be expressed in the logarithmic form—viz., we have :—

$$\int \frac{1}{\operatorname{sn} u}\, du = -\log \frac{\operatorname{cn}\tfrac{1}{2}u \operatorname{dn}\tfrac{1}{2}u}{\operatorname{sn}\tfrac{1}{2}u},$$

$$\int \frac{\operatorname{dn} u}{\operatorname{sn} u}\, du = \log \frac{\operatorname{sn}\tfrac{1}{2}u \operatorname{dn}\tfrac{1}{2}u}{\operatorname{cn}\tfrac{1}{2}u},$$

$$\int \frac{\operatorname{cn} u}{\operatorname{sn} u}\, du = \log \frac{\operatorname{sn}\tfrac{1}{2}u \operatorname{cn}\tfrac{1}{2}u}{\operatorname{dn}\tfrac{1}{2}u},$$

$$\int \frac{\operatorname{dn} u}{\operatorname{cn} u}\, du = -\log \frac{\operatorname{cn}(\tfrac{1}{2}u + \tfrac{1}{2}K) \operatorname{dn}(\tfrac{1}{2}u + \tfrac{1}{2}K)}{\operatorname{sn}(\tfrac{1}{2}u + \tfrac{1}{2}K)},$$

$$\int \frac{1}{\operatorname{cn} u}\, du = \frac{1}{k'} \log \frac{\operatorname{sn}(\tfrac{1}{2}u + \tfrac{1}{2}K) \operatorname{dn}(\tfrac{1}{2}u + \tfrac{1}{2}K)}{\operatorname{cn}(\tfrac{1}{2}u + \tfrac{1}{2}K)},$$

$$\int \frac{\operatorname{sn} u}{\operatorname{cn} u}\, du = -\frac{1}{k'} \log \frac{\operatorname{sn}(\tfrac{1}{2}u + \tfrac{1}{2}K) \operatorname{cn}(\tfrac{1}{2}u + \tfrac{1}{2}K)}{\operatorname{dn}(\tfrac{1}{2}u + \tfrac{1}{2}K)},$$

$$\int \operatorname{sn} u\, du = -\frac{1}{k} \log \frac{\operatorname{cn}(\tfrac{1}{2}u + iK') \operatorname{dn}(\tfrac{1}{2}u + \tfrac{1}{2}iK')}{\operatorname{sn}(\tfrac{1}{2}u + \tfrac{1}{2}iK')},$$

$$\int \operatorname{cn} u\, du = \frac{i}{k} \log \frac{\operatorname{sn}(\tfrac{1}{2}u + \tfrac{1}{2}iK') \operatorname{dn}(\tfrac{1}{2}u + \tfrac{1}{2}iK')}{\operatorname{cn}(\tfrac{1}{2}u + \tfrac{1}{2}iK')},$$

$$\int \operatorname{dn} u\, du = \log \frac{\operatorname{sn}(\tfrac{1}{2}u + \tfrac{1}{2}iK') \operatorname{cn}(\tfrac{1}{2}u + \tfrac{1}{2}iK')}{\operatorname{dn}(\tfrac{1}{2}u + \tfrac{1}{2}iK')},$$

$$\int \frac{\operatorname{cn} u}{\operatorname{dn} u}\, du = \frac{1}{k} \log \frac{\operatorname{cn}(\tfrac{1}{2}u + \tfrac{1}{2}K + \tfrac{1}{2}iK') \operatorname{dn}(\tfrac{1}{2}u + \tfrac{1}{2}K + \tfrac{1}{2}iK')}{\operatorname{sn}(\tfrac{1}{2}u + \tfrac{1}{2}K + \tfrac{1}{2}iK')},$$

$$\int \frac{\operatorname{sn} u}{\operatorname{dn} u}\, du = -\frac{i}{kk'} \log \frac{\operatorname{sn}(\tfrac{1}{2}u + \tfrac{1}{2}K + \tfrac{1}{2}iK') \operatorname{dn}(\tfrac{1}{2}u + \tfrac{1}{2}K + \tfrac{1}{2}iK')}{\operatorname{cn}(\tfrac{1}{2}u + \tfrac{1}{2}K + \tfrac{1}{2}iK')},$$

$$\int \frac{1}{\operatorname{dn} u}\, du = \frac{i}{k'} \log \frac{\operatorname{sn}(\tfrac{1}{2}u + \tfrac{1}{2}K + \tfrac{1}{2}iK') \operatorname{cn}(\tfrac{1}{2}u + \tfrac{1}{2}K + \tfrac{1}{2}iK')}{\operatorname{dn}(\tfrac{1}{2}u + \tfrac{1}{2}K + \tfrac{1}{2}iK')}.$$

The system of integrals may be written also as follows :—

$$\int \frac{1}{\operatorname{sn} u}\, du = -\log \frac{\operatorname{dn} u + \operatorname{cn} u}{\operatorname{sn} u},$$

$$\int \frac{\operatorname{dn} u}{\operatorname{sn} u}\, du = \log \frac{1 - \operatorname{cn} u}{\operatorname{sn} u},$$

$$\int \frac{\operatorname{cn} u}{\operatorname{sn} u}\, du = \log \frac{1 - \operatorname{dn} u}{\operatorname{sn} u},$$

$$\int \frac{\operatorname{dn} u}{\operatorname{cn} u}\, du = -\log \frac{1 - \operatorname{sn} u}{\operatorname{cn} u},$$

$$\int \frac{1}{\operatorname{cn} u}\, du = \frac{1}{k'} \log \frac{\operatorname{dn} u + k' \operatorname{sn} u}{\operatorname{cn} u},$$

$$\int \frac{\operatorname{sn} u}{\operatorname{cn} u}\, du = -\frac{1}{k'} \log \frac{\operatorname{dn} u - k'}{\operatorname{cn} u},$$

$$\int \operatorname{sn} u\, du = \frac{1}{k} \log (\operatorname{dn} u - k \operatorname{cn} u),$$

$$\int \operatorname{cn} u\, du = \frac{i}{k} \log (\operatorname{dn} u - ik \operatorname{sn} u),$$

$$\int \operatorname{dn} u\, du = i \log (\operatorname{cn} u - i \operatorname{sn} u),$$

$$\int \frac{\operatorname{cn} u}{\operatorname{dn} u}\, du = -\frac{1}{k} \log \frac{1 - k \operatorname{sn} u}{\operatorname{dn} u},$$

$$\int \frac{\operatorname{sn} u}{\operatorname{dn} u}\, du = -\frac{i}{kk'} \log \frac{k \operatorname{cn} u + ik'}{\operatorname{dn} u},$$

$$\int \frac{1}{\operatorname{dn} u}\, du = \frac{i}{k'} \log \frac{\operatorname{cn} u - ik' \operatorname{sn} u}{\operatorname{dn} u},$$

Only four of these expressions are imaginary, and by reducing them to real forms, we obtain the formulæ:

$$\int \operatorname{cn} u\, du = \frac{1}{k} \operatorname{arc\,tan} \frac{k \operatorname{sn} u}{\operatorname{dn} u},$$

$$\int \operatorname{dn} u\, du = \operatorname{arc\,tan} \frac{\operatorname{sn} u}{\operatorname{cn} u},$$

$$\int \frac{\operatorname{sn} u}{\operatorname{dn} u}\, du = \frac{1}{kk'} \operatorname{arc\,tan} \frac{k'}{k \operatorname{cn} u},$$

$$\int \frac{1}{\operatorname{dn} u}\, du = \frac{1}{k'} \operatorname{arc\,tan} \frac{k' \operatorname{sn} u}{\operatorname{cn} u},$$

Formulæ of Reduction for $\int \operatorname{sn}^n u\, du$, &c. We have

$$\frac{d^2}{du^2} \operatorname{sn}^n u = n(n-1) \operatorname{sn}^{n-2} u - n^2 (1 + k^2) \operatorname{sn}^n u + n(n+1) k^2 \operatorname{sn}^{n+2} u \ . \ . \ . \ (1)$$

and by means of this formula the integral of $\operatorname{sn}^n u$ may be reduced to depend upon the integrals of $\operatorname{sn} u$, $\operatorname{sn}^2 u$, $\frac{1}{\operatorname{sn} u}$, $\frac{1}{\operatorname{sn}^2 u}$ according as n is positive and uneven, positive and even, negative and uneven, negative and even.

The integral of $\operatorname{sn}^2 u$ involves the Zeta function; and the integral of $\frac{1}{\operatorname{sn}^2 u}$ may be deduced from that of $\operatorname{sn}^2 u$ by means of the formula:

$$\frac{d^2}{du^2} \log \operatorname{sn} u = k^2 \operatorname{sn}^2 u - \frac{1}{\operatorname{sn}^2 u} \ . \ . \ . \ . \ . \ . \ . \ (2).$$

Corresponding to (1) and (2) there are eleven other pairs of formulæ which involve the other eleven functions in place of $\operatorname{sn} u$, and differ from one another only in the k-coefficients. It can thus be shown that the integrals of the n^{th} powers of the twelve functions are all finitely expressible in terms of elliptic functions if n is uneven, and in terms of elliptic functions, and of the Zeta function, if n is even; and that the twelve formulæ of reduction are similar in form and such that from any one of them the other eleven may be deduced.[1]

[1] The paper will be printed *in extenso* in the *Messenger of Mathematics*. The first portion appears in the number for October, 1881.

6. *Sur les Séries Hypergéométriques.* *By* Professor HALPHEN.

[This paper was ordered by the General Committee to be printed *in extenso*, but is omitted by desire of the Author.]

TUESDAY, SEPTEMBER 6.

The following Reports and Papers were read :—

1. *Report of the Committee on Electrical Standards.*—See Reports, p. 423.

---

2. *Report of the Committee for the measurement of the Lunar Disturbance of Gravity.*—See Reports, p. 93.

---

3. *On the Rainfall Observations made upon York Minster by Prof. John Phillips, F.R.S.* *By* G. J. SYMONS, *F.R.S.*

The author commenced by noticing the experiments on rainfall made by Mr. Townley and by Dr. Heberden at Westminster in 1766, and elsewhere. Those by Prof. Phillips and Mr. Gray were made during the years 1832–5, when gauges were set up at York, with the following results:—

Museum garden, 2 inches above ground.	Total rain	21·81 in.	Ratio 100.
„ roof, 44 feet	„ „	17·39 „	„ 80.
Minster Tower, 213 feet	„ „	12·99 „	„ 60.

Which totals agree very well with Dr. Heberden's observations. Prof. Phillips' explanation of the above was that the drops of rain increased in volume on their descent through the moist lower strata of the atmosphere. The author remarked upon certain considerations which had been omitted by Prof. Phillips, such as the velocity of the wind and the fact that seasons which are windy are also cold and humid—and to Prof. Bache's report, presented to the British Association in 1838, in which he called attention to the important effect of eddy winds on the phenomena. He found that, of gauges mounted upon a lofty tower, those to leeward of the wind received the most water. A great alteration was made by elevating the gauge on a pole; thus, when those at the N.E. and S.W. angles received water in the proportion of 1 to 1·68, those elevated 6 feet above the parapet received it in the proportion of 1 to 1·08, and with a more moderate wind the quantities were yet nearer equality. Sir John Herschel also has shown that any sensible addition to the volume of a drop of rain in the way supposed would very materially raise its temperature. The author then adverted to Mr. W. S. Jevons' paper, published in the 'Philosophical Magazine' for Dec. 1861, in which he shows that the phenomena observed are all consistent with the theory that the fall of rain is practically identical at all elevations, while the observed differences are due to imperfect collection by the gauges, owing to deflection of the rain-bearing current by such obstacles as houses, towers, and even the gauges themselves. Mr. Dines (without knowledge of the last paper) came to a similar conclusion, as stated to the British Association in 1877, and this had subsequently been confirmed by observations on large surfaces, such as the roof of Messrs. Marshall's factory at Leeds, and upon one 5,000 square feet in area in survey. In the latter case (the height above the ground being 29 feet) the difference between the rainfall on the two localities was only 2 per cent.; instead of 20 per cent., as would be the case on the roof of a small building or near the edge of a large one.

4. *On Volta-Electric Inversion.* By Professor SILVANUS P. THOMPSON, *B.A., D.Sc.*

The author gives the name of *volta-electric inversion* to a phenomenon which is, for voltaic currents, the precise analogue of the thermo-electric inversion discovered by Cumming in the case of thermo-electric currents.

It is known that when voltaic cells are heated both their resistance and their E.M.F. are affected. The latter sometimes increases, sometimes diminishes. The latter phenomenon led the author to suspect the existence of a volta-electric inversion. This he discovered as occurring in a cell containing sulphuric acid of density 1·753, into which dipped electrodes of iron and copper. At 25° C. this cell gave a current which flowed through the liquid from iron to copper, the iron dissolving in the acid, with evolution of hydrogen at the copper pole. On heating the cell the current fell off, and became null between 140° and 150°, when it recommenced powerfully in the inverse direction, bubbles believed to be SO_2 coming off from the iron pole, the copper pole dissolving in the acid. The currents in question were true voltaic currents, being of much greater E.M.F. than the thermo-currents of an iron-copper pair, and being moreover accompanied by strong chemical action in the cell. The author cited as explanatory of this effect some experiments of Warburg on the electrolysis of strong sulphuric acid, which when electrolysed below 80° C. yielded only O and H gases; between 80° and 90° gave O at anode and at kathode H and S; but above 90° gave O at anode, S only at kathode. It was further pointed out that this discovery rendered possible a battery of two metals and one liquid, from which a constant current could be obtained without contact of dissimilar metals, alternate cells in the series being heated; and the copper of one cell should be joined to the copper of the next, and the iron of this to the iron of the next.

---

5. *On the Rotational Coefficient in Various Metals.* By E. H. HALL.

This communication treated of the recently discovered fact that when a conductor bearing an electric current is acted upon by a magnetic force at right angles to the current, an electro-motive force is set up in the conductor, the direction of this force being perpendicular to the plane of the electric current and the magnetic force.

Several articles upon the subject have already been published, but the present communication made known a few new facts not yet in print which had been ascertained quite recently during the author's short stay in the laboratory of Prof. Helmholtz in Berlin.

The numerical values given in the table below are in any case only tentative, and those which are marked thus (?) are particularly uncertain, being liable to errors of perhaps 100 per cent. or more. It is believed, however, that in every case the sign fixed to any number is correct.

Arranging the metals thus far examined in the order of magnitude of the transverse effect in them, we obtain the following table.

The numbers given are intended to be *proportional* only to the magnitude of the transverse effect, and not to have any absolute significance.

Iron	+ 78
Cobalt	+ 25
Zinc	+ 15 (?)
Lead	
Tin	− ·2 (?)
Brass	− 1·3 (?)
Platinum	− 2·4
Gold	− 6·8
Silver	− 8·6
Copper	− 10 (?)
Aluminium	− 50 (?)
Magnesium	− 50 (?)
Nickel	−120

More detailed information in regard to the behaviour of certain of the above metals may be found in articles before published by the author, and in one which probably appears in the current number of the 'Philosophical Magazine.'

---

6. *On a Dynamometer Coupling. By* Professors W. E. Ayrton, *F.R.S.*, *and* John Perry, *B.E.*

The instrument exhibited to the Section is one of a complete set of instruments designed by the author for measuring purposes in electric lighting, and in the transmission of power. The other instruments belonging to the set are—1st. A *dead-beat Galvanometer* or *Am-meter*, which measures accurately a strong electric current in ampères. It gives an immediate measurement of a rapid alteration in the current; when wound somewhat differently, this becomes the author's *Volt-meter*, which measures instantaneously an electromotive force in volts. 2nd. A *Photometer*, which gives the strength of a light in standard candles, and which enables the measuring operation to be performed in a very small room. 3rd. An *Ergometer*, which gives at one reading the horse-power which is being expended on an electric arc or in an incandescent lamp, or in any other electric circuit. That is, it gives in one reading the product of electro-motive force into current. The authors have called the instrument a *Power-meter*, but Sir William Thomson has given to it the name *Ergometer*. 4th. The present instrument; a *Dynamometer*, which measures the horse-power transmitted from one length of shafting to another in a factory, or the power given up to any machine.

Various dynamometers, as is well known, are in existence, but however suited they may be to laboratory conditions, they cannot be regarded as suitable for workshop use. In fact, they are to be called arrangements of scientific apparatus rather than dynamometers. The dynamometer described by the authors in their paper read before the Society of Telegraph Engineers last session may be seen in use by the students of The City and Guilds of London Technical College at Finsbury. It is capable of more general application than this, because it is used in the belting which drives a dynamo or any other machine. Although the principle of construction of this instrument is the same, they think it worthy of notice from its being capable of taking the place of an ordinary shaft coupling, and from its not being much more expensive than an ordinary shaft coupling. In fact, it consists of the two halves of an ordinary coupling, one keyed to each of the shafts which are to be coupled. The shape is slightly different from what is usual, and allows the connection of the two halves by means of the spiral springs. Now it is evident that if one shaft turns the other, it can only do so by pulling the springs, and the movement of the turning couple is proportional to the lengthening of the springs, that is, to the angular advance of one half of the coupling before the other half. Here are two light levers, by means of which this relative motion of the two halves produces a radial motion of a silvered bead, and the distance of this bead radially from the shaft can be read off on a scale. The scale reading, multiplied into the number of revolutions per minute, gives at once the horse-power transmitted through the coupling. The whole arrangement would appear to be nearly as small and insignificant as an ordinary coupling were it not for the disc of sheet iron, with its marginal flange, which is used to protect the levers and the bead. Everything except the bead is painted dead-black. The instrument exhibited has been designed to couple a Brotherhood Engine and a Brush Machine, and when the bead is close to the shaft and the speed is 800 revolutions per minute, the coupling transmits 18 horse-power. In the present position of the bead the springs are unstrained, and this is the case when no power is being transmitted. It is the authors' intention to attempt to introduce these couplings into every line of shafting in manufactories, so that the stream of power along every shaft may be measured and visibly made known at any distance from which the bead may be distinguished.

---

7. *On an Early Attempt at a Secondary Battery.* *By* Dr. C. W. Siemens, *F.R.S.*

8. *On an Electro-Ergometer.* *By* Professor Sir William Thomson, *M.A., F.R.S.*

9. *On a Problem in Stream Lines.* *By* Professor A. W. Rücker, *M.A.*

If ϕ = const. and ψ = const. be the equations to the curves of equal velocity-potential and to the stream-lines in the case of a liquid possessed of irrotational motion in two dimensions, let us, in accordance with a well-known property of these functions, assume

$$\phi + i\psi = -V(x+iy)\left\{1 + \frac{2a^2}{(x+iy)^2 + \frac{a^2}{4}}\right\}$$

Then, rationalising the denominator we get

$$\phi = -Vx\left\{1 + \frac{a^2}{x^2+\left(y-\frac{a}{2}\right)^2} + \frac{a^2}{x^2+\left(y+\frac{a}{2}\right)^2}\right\}$$

$$\psi = -V\left\{y - \frac{a^2\left(y-\frac{a}{2}\right)}{x^2+\left(y-\frac{a}{2}\right)^2} - \frac{a^2\left(y+\frac{a}{2}\right)}{x^2+\left(y+\frac{a}{2}\right)^2}\right\}$$

Now when x and y are very great compared with a $\psi = -Vy$, and ψ vanishes when $y=0$, and also when

$$x^2+\left(y-\frac{a}{2}\right)^2 = a^2 \text{ or } x^2+\left(y+\frac{a}{2}\right)^2 = a^2.$$

Hence, at an infinite distance from the origin, all the stream-lines are parallel to the axis of x, and that axis, together with the two circles whose equations are given above, constitutes a stream-line.

The equations thus solve the problem of the flow of a liquid past a cylindrical obstacle, the generating lines of which are perpendicular to the undisturbed direction of the flow of the liquid, and the boundary of which is such that a section at right angles to the generating lines is made up of the external portions of the circumferences of two equal circles which pass through each other's centres, the line of centres being perpendicular to the undisturbed lines of flow.

The expression for ϕ may conveniently be written in the form—

$$\phi = -Vx\left\{1 + \frac{a^2}{r^2} + \frac{a^2}{r'^2}\right\}$$

where r and r' are the distances from the centres of the two circles.

The above formulæ may also be arrived at from elementary considerations, and they have been tested, as applied to the electric current, in the Physical Laboratory of the Yorkshire College. The apparatus used was similar to that described by Prof. G. C. Foster and Dr. Lodge in the 'Proc. Phys. Soc.,' part iii., 1875, except in so far as brass bars were used as linear electrodes.

When the apparatus was adjusted so that the equipotential lines were, as nearly as possible, parallel to these bars, a portion of the tinfoil was removed, and the form of the disturbed lines determined.

At first, to test the accuracy of the method, some experiments were made when the part removed was circular. Afterwards the two equal circles were cut out.

Some specimen results are given below. As it was difficult to make the equipotential lines exactly parallel to the bars in the first instance, points on the same disturbed equipotential line were measured at approximately equal distances from the common chord of the two circles, and the constants given are, in each case, the means of those determined from a pair of such points.

The unit used is the millimetre. The quantity x is the distance from the diameter parallel to the bars, and is the case of the two circles at right angles to their common chord. $V = -1$.

TABLE I.—CIRCLE. RADIUS = 8·43MM.

Curve I.		Curve II.		Curve III.	
x	ϕ	x	ϕ	x	ϕ
4·92	19·73	10·43	16·25	16·04	20·22
7·66	19·36	15·59	15·80	19·37	20·17

TABLE II.—TWO CIRCLES. RADIUS = 6·38MM.

Curve I.		Curve II.		Curve III.	
x	ϕ	x	ϕ	x	ϕ
4·08	5·41	4·48	6·89	13·96	18·85
5·37	5·42	6·94	7·00	18·52	18·61

In each case those points only are given which are nearest to and furthest from the circle or circles.

---

10. *On Potential due to Contact.*[1] *By* S. LAVINGTON HART, *B.A., D.Sc., Scholar of St. John's College, Cambridge.*

The object of the paper is to illustrate and extend the analogy that exists between the action of an electrolytic cell and the behaviour of two metals in a gaseous medium, and to apply to both cases one simple law :—

The metal which, by reason of superior chemical affinity, combines with the electro-negative ion, receives thereby a negative charge, and acquires consequently (relatively to the medium) a negative potential.

If we take, for instance, a zinc-copper couple in acid or in air, two principal cases may present themselves :—

(i.) The metals are insulated ; in which case the zinc is negative to the medium, and this negative to the copper.

(ii.) The metals touch ; they are therefore at the same potential, but the medium is necessarily at a higher potential than this near the zinc, and at a lower in the neighbourhood of the copper. This difference of potential in the medium around the two metals has been determined, and is generally regarded as the difference of potential in the metals themselves.

In the experiments described, however, these two points are made clear, namely, that in air and in dilute acid :—

(i.) Metals insulated from one another, but in close proximity, are at different potentials, the more electro-negative being at a negative potential.

(ii.) Metals in contact are at the same potential.

The metals employed were iron and mercury, and the points referred to were proved by using an electrometer, one of the electrodes of which was put in connection with an iron wire dipping in mercury held in a funnel, to the neck of which was attached a fine glass jet, the drops from it forming within an iron cylinder put to the other electrode.

I obtained a deflection of thirty divisions, equivalent to a difference of potential of ·15 D (D being the E.M.F. due to a Daniell cell) by bringing up iron close to the falling drops.

In the verification of the second point a fresh question was raised, for it was found that a difference in potential was set up by different degrees of oxidation at the two surfaces of mercury (in the funnel, and at the end of the thread in the jet) due to

[1] Published in the *Philosophical Magazine*, November 1881.

difference in their capillary relations. In investigating this action I used a capillary tube in which was a thread of mercury broken by an air-bubble, and by causing this to run, I found that oxidation took place at the concave surface of the retreating column and rendered it negative to the advancing convex surface. I thus obtained as much as ·7 D as the difference in potential (by increasing the number of bubbles), while in the case of the falling drops a deflection indicating from ·5 D to ·6 D existed. The connection between this and oxidation was rendered evident by the possibility of increasing the deflection obtained by more rapid oxidation, and of reversing it by substituting for air a reducing gas, while if both funnel and jet were in an inert medium the absence of deflection would prove the second point: metals, when touching, *are* at the same potential.

---

11. *On the Electric Discharge through Colza Oil.*[1] *By* A. Macfarlane, *M.A., D.Sc., F.R.S.E.*

The electrical properties of colza oil examined were its dielectric strength and some phenomena accompanying the passage of the spark. By the dielectric strength of a substance is meant the ratio of the difference of potential required to pass a spark through the substance to that required to pass a spark through air under the same conditions. One set of observations gave 2·7 as the value for colza oil; another gave 2·5. The values now obtained for liquids are exhibited in the following table:—

Substance	Dielectric strength
Paraffin oil	3·7
Oil of turpentine	4·0
Paraffin (liquefied)	2·4
Olive oil	3·5
Colza oil	2·6

The passage of the spark was accompanied by the formation of gas-bubbles, but there was no deposition of solid particles. The behaviour of these bubbles was such as to indicate that they were formed at the positive electrode, and that they were positively electrified.

The method of the investigation is that described in 'Trans. R. S. E.,' vol. xxviii. p. 633.

---

12. *Représentation graphique de la Formule des Piles.*[2] *Discussion. Par* le Professeur C. M. Gariel, *Agrégé de Physique à la Faculté de Médecine de Paris, Ingénieur des Ponts et Chaussées.*

M. Gariel indique une représentation graphique de la formule bien connue qui donne l'intensité d'un courant, connaissant le nombre des éléments, la force électromotrice, la résistance de chacun d'eux et la résistance extérieure, et qui, par une construction très simple, permet de comparer cette intensité avec celle que donnerait dans le même circuit un seul élément. Cette construction qui ne comporte que le tracé de lignes droites est susceptible d'être donnée par un appareil mécanique fort simple qui fournit immédiatement le résultat par une seule lecture.

Une discussion analogue permet d'étudier le cas où les éléments sont réunis en quantité et particulièrement conduit à la solution du problème suivant: étant donnés un circuit et n éléments égaux, comment faut-il les grouper en m groupes de p éléments pour obtenir le courant maximum?

La règle est la suivante:—

[1] See *Nature*, vol. xxiv., p. 465.

[2] Le travail *in extenso* a paru dans le journal français *l'Electricien*, Nos. des 19 avril et 1er mai 1881.

On forme toutes les valeurs de $\frac{p\,p^1}{n}$ et $\frac{p^1\,p^{11}}{n}$, $p_1\,p^1$ et p^{11}, étant successivement les divers diviseurs de n rangés par ordre de grandeur, jusqu'à ce que deux de ces valeurs comprennent entre elles le rapport $\frac{\mathrm{r}}{\mathrm{R}}$ de la résistance d'un élément à la résistance du circuit extérieur: le nombre p^1 sera celui qu'il conviendra de prendre.

---

13. *On an Easy Method of making Carbon Cells for Galvanic Batteries.* *By* W. Symons, *F.C.S.*

At the Belfast meeting of the Association the author described a method of making carbon cells by repeatedly dipping paper moulds in a mixture of syrup and fine carbon. This is a practicable but tedious process. A much easier and more expeditious method is the following:—Mix together 15 parts of powdered gas carbon, 3 parts of wood charcoal, and 10 parts of lump sugar. Well shake down this powder, dry into paper moulds of the size and shape required, cylindrical being the most manageable. Bury the filled moulds in sand in a suitable iron or copper vessel, and gradually expose to a red heat. When cold remove the burnt paper from the now solid cells, and soak them in a syrup made of equal parts of lump sugar and water. Well dry the cells, wrap them up in paper, again bury in sand, and gradually expose them for some time to as strong a heat as practicable, but not less than a bright red heat. For this purpose the author has used an extempore furnace made of Fletcher's solid-flame burner, surmounted with a common unglazed earthenware drain-pipe, partially closed with an iron dome. This furnace is easily constructed, and is useful for a variety of purposes. The draught may of course be increased by adding a pipe to the iron dome. In the author's experience a carbon mixture of the above proportions is the best. Cells made with other kinds of carbon crack more or less, but the above mixture, with due care, does not crack.

---

14. *On an Antimonized Cellular Carbon Galvanic Battery.* *By* W. Symons, *F.C.S.*

Faraday, in his 'Experimental Researches,' p. 2012, 'On the Order of the Metallic Elements of Voltaic Circles,' places antimony highest of the metals tested by him with hydrochloric acid. This fact suggested to the author the construction of a battery made with carbon cells as described in the previous paper, with antimony precipitated on the carbon, using zinc rods unamalgamated and a solution of ammonium chloride, but, with very limited leisure, he has not been able to complete an efficient battery in time for this meeting. He, however, ventures to suggest such a battery as a useful one for general laboratory purposes, being somewhat similar to Smee's in action, but with much cheaper negative elements, and a more economical utilization of the zinc. By boring holes also in the carbons, he believes that polarisation will be diminished, by thus increasing the amount of efficient carbon surface and promoting the circulation of the liquid, but at present he has not had time to test this point. The carbon cells can be made small enough to be nearly close to the zinc, while, by having the containing vessels of an ample size, the constancy of the current will be enhanced. Another form of the battery which he proposes to make is with larger carbons and porous diaphragms, using for the outer liquid a mixture of antimonious chloride and ammonium chloride.

Perhaps it may not be amiss to add that plaster of Paris diaphragms can also be easily made with dry plaster. Provide an inner core or mould of turned wood, a little taper and with a shoulder the required thickness of the diaphragm; round this tie two thicknesses of stout blotting-paper, well shake down the dry plaster between the wooden core and the paper. Then immerse the whole in water. In a few minutes the diaphragm will be solid and can be removed from the mould.

15. *On the Absolute Sine Electrometer. By* Professor G. M. MINCHIN, *M.A.*

This is an electrometer in which use is made of the attracted disk and guard-plate principle.

The continuous plate and the guard plate are two brass plates, each about a foot square. They are kept at a constant small distance apart (being parallel to each other) by means of four ivory axes or pins driven through them near their corners. The attracted disc is a square of aluminium, its side being 3 centimètres long; it is suspended by means of two Wollaston platinum wires, each about 7 inches long, from a metallic piece at the top edge of the guard plate. The two plates can move, as a rigid body, round a fixed horizontal axis attached to the continuous plate. This system can be tilted out of the vertical position by means of a micrometer screw whose axis works horizontally against the lower portion of the continuous plate.

The disk (which is, of course, always in metallic contact with the guard plate) is, in the vertical position of the plates, flush with the guard plate. This flushness is obtained by means of four small adjustable screws fixed to the guard plate at the back of the disk; when the system of plates is tilted out of the vertical, the disk will remain in the flush position, unless it is attracted off the points of these four screws by some force.

Any motion of the disk is observed by means of a microscope rigidly attached to the back of the guard plate; the focal length is $\frac{1}{4}$-inch.

If the continuous plate is connected by a wire with one electrified body, while the disk and guard plate are connected with another, the disk will be drawn off the screw-points, unless the system of plates is sufficiently tilted out of the vertical.

If w = weight of disk, θ = angle of deviation of plates from vertical, d = distance between the plates, E = difference of potential of the sources in connection with the two plates, S = area of disk, the equation of equilibrium of the disk when it is *just* out of contact with the screws is

$$\frac{SE^2}{8\pi d^2} = w \sin \theta.$$

The force measured is thus proportional to the *sine* of the angle of deflection from the vertical—whence the name of the instrument.

Usually the sine and the circular measure will be equal, since the deflections will not amount to many degrees.

In the instrument (which has been constructed by Mr. Groves of Bolsover Street) $d = \cdot 516$ millimètres, $w = \cdot 2568$ grammes, the *vertical* distance between the axis of suspension of the plates and the point of the tilting micrometer screw = 15 inches, the diameter of the head of this screw is 3 inches, its circumference is divided into 1,000 equal parts, and the pitch is $\frac{1}{60}$-inch. Hence the equation of equilibrium (employing the absolute measures of weight and length) is

$$E = \cdot 0456\sqrt{m},$$

where m is the number of divisions turned through on the micrometer screw-head from the vertical position of the plates.

Since it is difficult to know when the vertical position is attained exactly, a differential method is resorted to. An observation is made with n cells and then with n' of the same cells, and if, when the disc is just attracted off the screws, the readings of the micrometer screw-head are m and m', we get

$$E = \cdot 0456\sqrt{\frac{m-m'}{n^2-n'^2}},$$

where, of course, $m - m'$ is known, although m and m' are separately unknown.

There are four adjustments which must be carefully attended to, the most difficult being the determination of the distance d. This (on the suggestion of Professor Carey Foster) was determined by taking three readings with a spherometer at three points of the aperture of the guard plate, before and after the insertion of mica washers on the four ivory axes which connect the plates.

Very few experiments have yet been made; but the E.M.F of the cells in a battery of Leclanché elements was determined by seven experiments, all of which very closely agreed. The value obtained was—

·00475

absolute electrostatic units.

The author is constructing a battery of 50 Grove cells, specially adapted to the measurement of E.M.F.

A deflection of the disk is easily observed with about 6 Leclanché cells, or less; —and a second deflection is then taken with a large number—20, 30, 40, or 50.

WEDNESDAY, SEPTEMBER 7.

The following Reports and Papers were read:—

1. *Report of the Committee on a Standard of White Light.* See Reports, p. 126.

2. *Report of the Committee on Luminous Meteors.*—See Reports, p. 290.

3. *Report of the Committee on the Thermal Conductivity of Rocks.* See Reports, p. 126.

4. *A Contribution to the History of the Algebra of Logic.* *By the* Rev. R. Harley, *F.R.S.*

The author pointed out that the earlier and limited conceptions of algebra, that it is a universal arithmetic, or such a modification of arithmetic as is necessitated by the use of a symbolical language, had prevented for long the connection between the fundamental principles and processes of algebra and of logic from being discovered. To perceive that algebra embraces not only arithmetic in its widest sense, but the whole science of symbolical reasoning, formed a most important step in logic as well as in mathematics. This was first apprehended to some extent by certain of the more philosophical analysts of the earlier part of the present century, and was more clearly enumerated by Dr. F. Gregory in 1838. Henceforward, as arithmetic had proved the 'science of suggestion' to algebra, so the latter, in the hands of Boole, proved the science of suggestion to logic. In his works, 'The Mathematical Analysis of Logic,' and, more fully and systematically, in his 'Laws of Thought,' he developed the science of logic in algebraical forms. This mode of expression is justified on strictly logical grounds. It is founded, not upon any supposed relationship or analogy between the conceptions or ideas with which logicians and mathematicians are respectively conversant, but upon the fact, established by actual examination, that the formal laws of thought in logic are identical with those of an algebra, or science of number, in which the symbols represent, not all numbers, but only those which we designate by nought and unity. The author next proceeded to consider the symbolical methods in logic which owe their origin to the 'Laws of Thought,' by Boole. He noticed particularly the method of Professor Jevons, as developed in 'The Principles of Science'; of Mr. Hugh McColl in his 'Calculus of Equivalent Statements,' and of Dr. Macfarlane, in his 'Algebra of Logic.' Reference was also made to the recently published work of Mr. Venn, on 'Symbolic Logic,' which the author characterised as a powerful defence of the Booleian method.

5. *On the Illuminating Powers of Incandescent Vacuum Lamps with measured Potentials and measured Currents. By* Professor Sir William Thomson, *M.A., F.R.S., and* James T. Bottomley, *M.A.*

The electromotive force used in these experiments was derived from Faure's secondary batteries, kindly supplied for the purpose by the Société la Force et la Lumière in their London office.

Two galvanometers were used simultaneously, one (called the *potential galvanometer*) for measuring the difference of potentials between the two terminals of the lamp, the other (called the current galvanometer) for measuring the whole strength of the current through the lamp.

The potential galvanometer had for its coil several thousand metres of No. 50 (B.W.G.) silk-covered wire (of which the copper weighs about $\frac{1}{20}$ gramme per metre, and therefore has resistance of about 3 ohms per metre). Its electrodes were applied direct on the platinum terminals of the lamp.

The current galvanometer had for its coil a single circle of about 10 centimetres diameter, of thick wire placed in the direct circuit of the lamp, by means of electrodes kept close together to a sufficient distance from the galvanometer to ensure no sensible action on the needle except from the circle itself. The directive force on the needle which was produced by a large semi-circular horse-shoe magnet of small sectional area was about $2\frac{1}{2}$ c.g.s., or 15 times the earth's horizontal magnetic force in London. This arrangement would have been better for the potential galvanometer also than the plan actually used for it, which need not be described here. The scale of each galvanometer was graduated according to the natural tangent of the angle of deflection, so that the strength of the current was simply proportional to the number read on the scale in each case.

Three lamps were used, Nos. II. and III. of a larger size than No. I. The experiment was continued with higher and higher potentials on each lamp till its carbon broke.

The illuminating power was measured in the simplest and easiest way (which is also the most accurate and trustworthy), by letting the standard light and the lamp to be measured shed their lights nearly in the same direction on a white ground (a piece of white paper was used); and comparing the shadows of a suitable object (a pencil was used); and varying the distance of the standard light from the white ground till the illuminations of the two shadows were judged equal. The standard used was a regulation 'standard candle,' burning 120 grains of wax in the hour. The burning was not actually tested by weighing; but it was no doubt very nearly right; nearly enough for our purpose, which was an approximate determination of the illuminating powers of each lamp through a wide range of electric power applied to it. The following results were obtained :—

LAMP NO. I.

No. of Experiment	Cells	Volts	Webers	Volts × webers ÷ 10 ÷ kilogram-metres	Horse-power	Candles	Candles per horse-power
1	26	56·9	1·21	6·88	·093	11·6	125
2	30	65·5	1·46	9·56	·129	25	194
3	32	70·2	1·64	11·51	·156	42	263
4	33	71·8	1·74	12·48	·170	38	224
5	34	74·1	1·81	13·42	·181	44	243
6	35	76·1	1·82	13·86	·187	55	294
7	36	78·0	1·99	15·52	·210	63	300
8	37	80·3	2·06	16·54	·224	66	295
9	38	81·9	2·06	16·88	·228	76	333
10	39	84·6	2·06	17·43	·235	82	349
11	40	87·0	2·10	18·27	·247	84	340
12	42	90·9	2·17	19·72	·267	102	382
13	44	92·0	2·17	19·96	·270	89	330
14	46	99·1	2·21	21·91	·296	114	385
		Carbon of lamp broke with same power, immediately after the measurement of the light was completed.					

LAMP No. II.

No. of Experiment	Cells	Volts	Webers	Volts × webers ÷ 10 ≑ kilogram-metres	Horse-power	Candles	Candles per horse-power
1	40	89·7	2·207	19·8	·27	49	181
2	42	93·3	2·296	22·42	·29	68	234
3	43	95·4	2·38	22·71	·31	76	245
4	44	98·8	2·49	24·60	·33	101	306
5	46	103·0	2·63	27·09	·37	117	316
6	50	106·9	2·74	29·29	·40	147	367
7	52	110·8	2·85	31·56	·43	189	440
8	54	117·0	2·95	34·53	·47	196	417
9	56	119·8	2·95	35·34	·47	186	388
10	58	121·8	2·98	36·29	·49	177	361
11	40	87·0	2·14	18·62	·25	35	140
12	42	89·7	2·24	20·09	·27	42	156
13	60	122·8	3·06	37·58	·51	186	365
14	62	126·0	3·13	39·44	·53	180	340
15	66	132·4	3·24	42·89	·57	222	383
	70	Carbon of lamp broke.					

LAMP No. III.

No. of Experiment	Cells	Volts	Webers	Volts × webers ÷ 10 ≑ kilogram-metres	Horse-power	Candles	Candles per horse-power
1	40	82·3	2·85	23·45	·31	68	219
2	50	101·8	3·90	39·70	·54	195	361
3	60	Carbon of lamp broke.					

Some of the irregularities of the results in the preceding tables are very interesting and important, as showing the effect of the blackening of the glass by volatilization of the carbon when too high electric power came to be applied.

The durability of the lamp at any particular power must be tested by months' experience before the proper intensity for economy can be determined.

---

6. *On Photometry, with Experiments. By* Professor Sir WILLIAM THOMSON, *M.A., F.R.S.*

---

7. *On the Dynamical Theory of Radiation.*[1] *By* Professor ARTHUR SCHUSTER, *Ph.D., F.R.S.*

All theoretical investigations on radiation and absorption are confined to the consideration of an enclosure of uniform temperature. As no observation can be carried on in such an enclosure the theoretical results can only be adapted to the actual phenomena by making an assumption contained in Prevost's law that the radiation of the body is a function of the temperature only. It is the object of this paper to give some considerations which tend to show that this assumption is not justified. Imagine a Bunsen burner with a soda bead in it. The spectroscope will show the well-known yellow sodium lines; but we know that the sodium molecule is also capable of sending out certain rays in the green part of the spectrum. These rays are so weak, in the case under consideration, that they escape observation. We conclude from the appearances that the internal radiation

[1] Printed in full, *Phil. Mag.*, October 1881.

in the sodium vapour placed in the Bunsen flame is strong for a certain set of yellow vibrations, and weak for a certain set of green vibrations. If the Bunsen flame is now removed into an enclosure the temperature of which is equal to itself, the internal radiation in the green will suddenly be raised, while that in the yellow will not be (appreciably) affected. As there must be some relation between the internal radiation and the energy of vibration of the molecules, the green vibrations will be raised in intensity and be made more nearly equal to the yellow vibrations.

The following may show a little more clearly that the relative intensities of the vibrations need not be the same when the body is placed in an enclosure of uniform temperature, as when it is allowed to radiate into space.

Imagine a set of molecules not losing any heat by radiation, and assume that the molecules are, like the sodium molecules, capable of vibrating in two distinct periods, one corresponding to the yellow, and one corresponding to the green rays. There is a constant interchange between energy of translatory motion and energy of vibratory motion, and we imagine that the energy of translation is more easily transformed into yellow vibrations than into green vibrations. If the average energy for each set remains constant, it is because the energy of vibration is at the same time for other molecules transformed into energy of translation, and the yellow vibrations more easily than the green vibrations. The mathematical calculations of Maxwell and Boltzmann have shown that when the final equilibrium is reached, the final energy of vibration for the two periods must be the same. Imagine now the gas to be taken out of the enclosure and allowed to radiate into space. During the first instant, the yellow and the green vibrations will be of the same intensity, but very soon the molecular encounters will show their influence. We have assumed that yellow vibrations are more easily produced than green vibrations. While, therefore, the green vibrations are allowed to decrease in intensity, that of the yellow rays is constantly renewed by the encounters. It follows that the yellow rays will now appear the brighter, though in the enclosure of uniform temperature the energy of radiation for the green light was as large. The mere fact therefore that we observe lines of different intensities in the spectra of bodies is not in itself sufficient to invalidate Boltzmann's theoretical conclusion. But other considerations show that these conclusions are not supported by experiment. Thus, from the ratio of the two specific heats of mercury vapour, Boltzmann concludes that the molecule of mercury is a rigid particle, incapable of rotating or vibrating. It is suggested that forces due to the vibrations themselves, which have been neglected by Boltzmann, may be the cause of the discrepancy between theory and experiment.

---

8. *On a New Electrometer and some preliminary Experiments on Voltaic Action. By* J. Brown.

The author exhibited and described an instrument for measuring the difference of potential of two substances in contact while immersed in any desired gas. The metals to be examined are formed into a pair of quadrants fixed on an ebonite support in the apparatus, and their potential-difference is examined by means of a needle similar to half that in Sir William Thomson's electrometer, swinging over the slit between them, and suspended by a platinum wire, ·001-inch diameter from a torsion head at the top of an ebonite tube rising from the cover of the airtight metal case enclosing the quadrants, and into which any required gas can be introduced. The needle is electrified by connecting its suspension wire to either pole of a 100-cell Daniell battery, and its deflections are observed by mirror and scale. One quadrant is kept permanently connected with the earth, while a wire, joined to the other and passing airtight through the case, provides means for connecting the two together metallically, or one to each pole of any cell with the E.M.F. of which it is desired to compare their potential-difference either by Kohlrausche's method or that of Sir William Thomson ('B.A. Report,' 1880).

As the observed potential-difference of copper and zinc continually decreases with the oxidation of their surfaces in the air, a series of observations was made to ascertain the time-rate of this decrease, in order if possible to find what the true potential-difference was when the surfaces were perfectly clean, as compared with a Daniell cell. A represents one series obtained from commercial sheet zinc and copper by Thomson's method, and B another from redistilled zinc and commercial copper by Kohlrausche's method:—

A.	Minutes after cleaning	9	51	74	108		
	Potential-difference	·80D	·71D	·67D	·66D		
B.	Minutes after cleaning	13	21	74	115	185	3,700
	Potential-difference	·82D	·81D	·77D	·75D	·74D	·64D

From these it is evident the potential-difference would not be far under ·9D at the time of cleaning, and considering that, even when just cleaned, the plates cannot be considered quite clean, this value corresponds very well to the ratio of the difference of the heats of combination of copper and zinc with oxygen to the heat-equivalent of a Daniell cell—according to Thomsen ·9D.

When the quadrants were wet with distilled water, the potential-difference was ·82D to ·88D. When the copper was wet with copper sulphate solution, and the zinc with zinc sulphate, thus constituting the analogue of a Daniell cell, the difference of potential was ·98 Daniell.

The experiments seem to support the view, that the potential-difference of substances in contact is dependent on the chemical action going on at their exposed surfaces.

9. *On a Wave Apparatus for Lecture purposes, to illustrate Fresnel's conception of Polarised Light. By* C. J. Woodward, *B.Sc.*

10. *On a Microscope with arrangements for illuminating the sub-stage.*[1] *By* Edward Crossley, *F.R.A.S.*

The light from the lamp is thrown into the hollow horizontal axis of the microscope with the aid of the bull's-eye condenser, and by a prism placed in the centre of this axis, is reflected forwards in the direction of the axis on which the swinging sub-stage turns.

The arm of the swinging sub-stage is made in the form of a box, and carries a second prism in the axis on which it moves, so as to intercept the rays of light coming from the first prism, and reflect them in the direction of the arm or box.

At the end of the box is a third prism, which throws the rays of light forward on to the mirror by means of which they are finally directed to the object on the stage.

No change in position of the microscope on its horizontal axis affects the direction of the light from the lamp; and whatever the position of the swinging sub-stage, whether above or below the stage, the illumination remains constant upon the object. Thus the greatest facility is given for illuminating the object at any angle, and seeing which is most suitable.

The prisms are 1-inch, and give sufficient light for a $\frac{1}{16}$-in. object-glass with a Ross B eyepiece, using, of course, a suitable condenser beneath the stage. The field of a 4-inch object-glass is also fully covered.

11. *On a New Polarising Prism.*[2] *By* Professor Silvanus P. Thompson, *B.A., D.Sc.*

The author described and exhibited a new polarising prism of Iceland spar so cut that the axis of the prism is exactly at right angles to the optical axis of the crystal, and that the film of Canada balsam, by which the ordinary ray is totally reflected, is in a principal plane of section.

[1] Published *in extenso* in the *Journal of the Royal Microscopical Society for* 1881, p. 653.

[2] Printed *in extenso, Phil. Mag.*, Nov. 1881.

The Nicol prism has several defects. Its field is narrow, being limited on one side by the ordinary ray, which ceases at a certain angle to be totally reflected; and at the other by vanishing of the extraordinary ray by total reflexion; the limit of the field in this direction being further reduced by the occurrence of a blue iris, within which faint interference-fringes may be discerned. The limitation of the extraordinary ray arises from the arrangement of the prism, in which the inclination of the incident rays to the optic axis differs widely, producing the effective result that at a certain angle the extraordinary index is at a value not only greater than its minimum, but greater than that of the balsam.

The author's new prism obviates this, by employing spar so cut that the optic axis is exactly at right angles to the axis of the prism, and that the balsam film is parallel to the optic axis. The extraordinary rays, which lie in a plane containing the axis of the prism and at right angles to the optic axis, are all therefore transmitted, and the limitation on this side of the field is therefore removed. Of other rays it will be noted that, as the angle at which they cut the optic axis diminishes, their angle of incidence on the balsam film increases, instead of diminishing. This is, however, of no moment, as the aperture of the field in a principal plane of section containing the optic axis of the crystal is still over 90°. The available aperture of the new prism is about 10° greater than that of the Nicol Prism, and its 'lateral' aperture is as great as that of the Nicol.

The end faces are also more nearly normal to the axis of the prism, thereby reducing loss of light by reflexion.

12. *On an Overlapping Spectroscope.* *By* James Love, *F.R.A.S., F.G.S.*

In the instrument described by the author, one spectroscope was fixed, another being capable of rotation about its own axis, and of a small angular movement in their common plane, about a line passing through the point of intersection of their axes. The light which had passed through the movable spectroscope was reflected at the surface of the dispersion prism of the fixed spectroscope, and entered the eye looking along its axis. The results obtained by the author, in working with this instrument, differ in some respects from those already described by previous observers.

13. *On Change of Density at the Melting Point.* *By* James Love, *F.R.A.S., F.G.S.*

It is commonly supposed that bodies, as a general rule, contract their dimensions, and rapidly become more dense, as they pass from the liquid to the solid condition; and that those bodies which expand and become less dense on solidifying, such as water and cast iron, are exceptions to the general rule.

For the purpose of testing this so-called rule I have experimented on a few bodies at their melting points, and find that, as far as the experiments go, the 'exceptions' are sufficiently numerous to form a class by themselves. The method used was to heat the body to its melting temperature and observe whether the solid would *float* or *sink* in its own liquid. The bodies experimented on may be arranged into two classes, namely: Class A. Bodies whose solids *sink* in their own liquid, and Class B. Bodies whose solids *float* in their own liquid; or, for shortness, sinking solids and floating solids. They are as follows:—

Class A.—Sinking Solids.

Lead; tin; solder = 1 sn. + 1 pb.;
Resin; tallow; butter; lard; beef fat; mutton fat.

Class B.—Floating Solids.

Antimony; copper; zinc; cast iron;
Wrought iron upon cast; phosphor bronze;
Gunmetal = 16 cu. + 2 sn. + 1 zn.;
Brass = 16 cu. + 8 zn. + 1 pb.;
White metal = 1 cu. + 6 sn. + 12 zn.;
Another white metal = 2 cu. + 3 sb. + 24 sn.;

With most of these bodies the observations were easily made, as the sinking or floating was very decided; but in a few cases the observations needed a considerable amount of care. For instance, solid lead would readily sink when the temperature of the liquid was much above its melting point; but just at its melting point the sinkage was so very slight that there was some difficulty in determining whether the solid really did sink or not, a thin film of dirt being quite sufficient to keep it from sinking. With phosphor bronze, brass, and the second white metal, the flotation of the solid was very slight; but with the other bodies of Class B the floating was very decided. Copper, a body usually given as a sinking solid, floats with considerable buoyancy.

14. *On Drops and Capillarity.* *By* Dr. T. Woods.

The intention of this paper is to show that every liquid has a specific volume of drop, a definite number of drops of each liquid always occupying the same bulk under similar circumstances; and that, however varied circumstances may be, provided they change equally with all, the relation of volume of drop is maintained between the several liquids examined.

In it is also shown that this specific volume is proportional to the capillarity of the liquids—the greater the capillarity the larger the drop.

It is suggested that this property may be useful in analysis—a ready method, for instance, of detecting the amount of dilution of a fluid.

15. *On Binaural Audition.*—Part III.[1] *By* Professor Silvanus P. Thompson, *B.A.*, *D.Sc.*

The beats of mistuned consonances of the form $n : 1$ have lately claimed some attention on account of the revival of the dispute between Dr. König and the mathematical acousticians concerning the origin of the difference-tones or grave harmonics, König holding to Smith's theory that the beats, when sufficiently rapid, pass into beat-tones, which all mathematical physicists agree is physically impossible if the tones are simple, and if so small an amplitude that the squares and higher powers of the displacements may be neglected A very important paper on this matter, by Mr. Bosanquet of Oxford, has lately appeared ('Phil. Mag.' June 1881), in which he states: (i.) that these tones are subjective; (ii.) that they consist of variations in intensity of the lower tone; (iii.) that if the squares and higher powers of the displacements be not neglected in the equations, a term appears having a period whose frequency is the difference of the frequencies of the generating tones, as required by Helmholtz's theory of the difference-tones.

This question was alluded to in the author's previous papers on Phenomena of Binaural Audition ('Brit. Ass. Rep.' 1877, 1878). He found *beats* to be heard, but not *differential tones*, from two tones led separately to the two ears.

The author has lately examined with care the beats of the mistuned unison, octave, twelfth, and double-octave, bringing the sounds separately to the two ears by tubes. He has heard beats in all these cases, and in every case found them to consist of variations in intensity of the lower tone. The use of resonators intensified the phenomena.

The author also recounted experiments in which partial interference was obtained between an objective tone, and a subjective tone imposed upon the ear by fatigue.

He also announced a new illusion of binaural hearing due to fatigue, the apparent direction of a source of sound being altered by the previous fatigue of one ear.

16. *On Differential Resolvents.* *By the* Rev. Robert Harley, *F.R.S.*

[1] Printed in full, *Phil. Mag.*, Nov. 1881.

17. *An Analysis of Relationships.* *By* A. MACFARLANE, *M.A.*, *D.Sc.*, *F.R.S.E.*

The paper contained a summary of the notation and elementary laws of an analytical method of dealing with such questions as, in the simplest cases, may be dealt with graphically by means of the genealogical tree. The subject is a special branch of the algebra of logic, and its development appears to the author to throw much light upon the fundamental principles of that science. The method has been applied to test the *Systems of Affinity and Consanguinity* of Dr. Morgan of Rochester, New York.

Section B.—CHEMICAL SCIENCE.

President of the Section—Professor A. W. Williamson, Ph.D., LL.D., F.R.S., V.P.C.S.

[For Professor Williamson's Address see next page].

THURSDAY, SEPTEMBER 1.

The following Report and Papers were read:—

1. *Report of the Committee on the Method of Determining the Specific Refraction of Solids from their Solutions.*—See Reports, p. 155.

---

2. *On a Process for Utilising Waste-products and Economising Fuel in the Extraction of Copper. By* J. Dixon.

---

3. *On Metallic Compounds containing Bivalent Hydrocarbon Radicals.* Part II. *By* J. Sakurai.

In a former communication ('Brit. Ass. Report,' 1880) a new organo-mercury compound was described, of which the interesting feature was the bivalent character of the hydrocarbon radical contained in it, viz. methylene; this being, so far as I can ascertain, the first body ever obtained of its class.

The bivalent function of the organic radical, as well as of the metal, naturally suggests the existence of another compound, similar to the first, but containing an additional atom of mercury, thus:—

$$1° \ I\,CH_2HgI.$$
$$2° \ I\,HgCH_2HgI.$$

This second compound, which is related to methylene iodide in the same way as mercuric iodomethide (CH_3HgI) is to methyl iodide, can be easily obtained by exposing a mixture of methylene iodide, with an excess of mercury, to the action of light. It is desirable to add a little mercuric iodide, so as to form mercurous iodide, whose action has been fully explained in the paper already referred to. It is also necessary to add a sufficient quantity of ether, so as to keep the mixture in the fluid condition, even towards the end of the reaction. The reaction takes from one to several days, according to the state of weather and frequency of shaking.

In order to get the compound in a state of purity the following plan was adopted:—Ether is distilled off, and the residue is digested with a strong aqueous solution of potassic iodide. It is washed, first with water containing potassic iodide, and afterwards with pure water, till the washing is free from iodide, and then dried. It is now heated with methylene iodide, whereby any excess of mercury collects at the bottom of the beaker into a globule, leaving above it a clear yellow solution. The latter is decanted, and, on cooling, crystals are rapidly deposited; the first crops consist of pure di-mercury compound, whilst later portions and the mother liquor contain the mono-mercury compound. The first portions are drained, washed with methylene iodide, and then thoroughly with ether till a drop of the washings rapidly evaporates without leaving any oily residue.

Di-mercury methylene iodide thus obtained is a yellowish crystalline powder insoluble in all the ordinary solvents, hot methylene iodide being the only liquid capable of dissolving it.

It melts somewhere about 230° C., with partial decomposition. By acting upon it with iodine, we get, as the only products, mercuric iodide and methylene iodide:

$$I\,HgCH_2HgI + 2I_2 = 2HgI_2 + CH_2I_2.$$

Analytical results are shown below:—

	I.	II.
Substance taken	0·580	0·423
Pure iodine taken	0·556	0·4731
„ „ left	0·11592	0·1513
„ „ used up	0·44008	0·3218

Also,

	I.	II.
Mercuric sulphide	0·406	0·2939

These data give the following numbers per cent.:—

	I.	II.	Calc. for $CH_2Hg_2I_2$.
Iodine needed	75·87	76·08	76·05
Mercury	60·34	59·91	59·88

The same compound can with equal ease be obtained from mono-mercury compound (CH_2HgI_2), by simply mixing it with some mercury, mercuric iodide, and ether, and exposing the mixture to the action of light, with frequent shaking, as before.

By heating di-mercury methylene iodide with a dilute solution of hydric chloride we get mercuric iodomethide:—

$$I\,HgCH_2HgI + HCl = I\,HgCH_3 + Hg\frac{I}{Cl}.$$

The insoluble compound, which was in the previous paper supposed to be $CH_2Hg_2I_2$, has been re-examined with care, and is found to yield iodoform by the action of iodine, and not methylene iodide. The numerical result of analysis remains, however, almost the same. It is, therefore, in all probability, a compound of iodoform with mercury, having the formula $CH\,Hg_3I_3$, and containing a trivalent radical. This compound is related to iodoform, in the same way as mercuric iodomethide is to methyl-iodide, or dimercury-methylene-iodide to methylene-iodide. We may, therefore, be now supposed to possess the following series of organo-mercury compounds:—

$$CH_3(HgI),$$
$$CH_2(HgI)_2, \text{ and } CH_2HgI_2,$$
$$CH(HgI)_3.$$

In conclusion, I wish to record my best thanks to Professor Williamson for his able counsel and kind assistance, and to Mr. E. E. Berry for some of the preparations and analyses.

The President delivered the following Address:—

The Growth of the Atomic Theory.

It has been thought desirable that, on the occasion of this half-centenary celebration of the foundation of our great Association, some notice should be presented to the members of what has been doing in the respective branches of science during the period of our activity; and I have, accordingly, traced out for your consideration a very imperfect sketch of the theories which guided chemical inquiry at the beginning of that period, and of the leading changes which have been wrought in them by fifty years' work.

There is, perhaps, hardly any branch of science which during the last fifty years has made such great and steady progress as Chemistry. Let anyone compare recent dictionaries of the science (including the bulky supplements, which contain a record of the chief discoveries made while the body of the work was being compiled) with a treatise of chemistry fifty years old. Let him compare a published record of one year's progress of the science fifty years ago with one of modern date. Let him compare, as far as may be possible, the number of men who formerly devoted their whole time and energy to the advancement of chemistry, or who were engaged in industrial pursuits involving a knowledge of the science, with the corresponding number now-a-days. Let him count up the services which chemistry had rendered to common life at the commencement of the epoch with those which it has now to show.

Everywhere he will see marvellous evidences of increasing growth. But if he be a reflecting man, he will not be satisfied with wondering at results: he will endeavour to trace them to their causes, and to discover the guiding principles which have brought them about: he will try to derive, from a knowledge of those guiding principles, a perception of the means by which such progress can best be continued and extended—how it can be most effectively directed to the benefit of his fellow-men.

It is on this aspect of the question that I propose to address you to-day.

The process of scientific investigation includes a great variety of operations, which may be considered under three headings, mental, sensual, and physical. We think, we observe, and we work with our hands. In planning a new experiment we call to mind what is known of the phenomena in question, and form an opinion as to what is likely to happen under conditions somewhat different from those which existed in previous experiments. We regulate by careful observations the necessary manual operations, so as to obtain with accuracy the desired conditions for the new experiment, and we observe attentively the changes which take place in the course of that experiment. The result of such observations is sometimes in accordance with our anticipation, but very frequently at variance with it. If it accords with our anticipation, we put on record the extension which it has given to the application of the general theory on which that anticipation was founded. But if the result is not what we expected, we carefully and critically revise the reasoning which had led us to expect a particular result, and often repeat the same experiment with greater care, or some modification of it.

Materials for a new theory are gained when logically faultless reasoning, checked by accurate observations, have led to results which could not have been foreseen by the aid of any previous theory. When a theory has thus gained a footing in science, it serves as a guide in further work. It guides us in arranging known facts. It guides us to the discovery of new facts. Sometimes it does these things for a short time only, and is then superseded by some more general theory derived from a wider and more comprehensive view of the facts.

There is, perhaps, nowhere so severe and rigorous a test of the truth of an idea as that which is afforded by its use in any accurate department of experimental science; and it is worth while, on philosophical grounds, to consider briefly the conditions of growth of the chief chemical theories which have withstood this ordeal and proved themselves to be trustworthy guides in experimental science.

Now as far as I know them, the general theories which have played the chief part in the development of chemistry are mere condensed statements of fact.

Every thoughtful man of science has doubtless indulged in speculations to find the cause of facts which are as yet unexplained; has imagined some fundamental condition or property of matter which might cause it to produce effects such as are witnessed. It is to be hoped that the time may be far distant when men of science will confine their thoughts within the range of ideas which are proved to be true. But it is most important that they should not confuse such hypothetical speculations with theories which have received experimental verification, and that while employing any theory, they should not lose sight of the limits within which it has been proved to be correct, beyond which it can only be used as an hypothesis.

The foundation of the science of chemistry was laid by the discovery of chemical elements; those distinct varieties of matter which we can neither produce nor destroy. Chemical science treats of those changes of property in matter which can be represented as due to changes of combination of elementary atoms. It knows nothing of the production or destruction of those elementary atoms. Speculations respecting their ultimate form or structure will have found a place in the science as soon as such speculations have helped to arrange the facts which are known, and to discover new chemical facts.

At the commencement of our epoch chemists had classified elements according to their electro-chemical properties. Chemical analysis had established the fact that a good many compounds could be represented as consisting of elementary atoms of two kinds combined in small number. Thus carbonic oxide and carbonic acid had been found to possess respectively a composition which could be represented (adopting our present atomic symbols) by the formulæ CO and CO_2, water by the formula H_2O, marsh gas CH_4, olefiant gas CH_2. The oxides and acids of nitrogen were represented by formulæ corresponding empirically to those which we now adopt. So also ammonia and hydric chloride had their present formulæ. Sulphurous and sulphuric acid had the respective formulæ SO_2 and SO_3. Phosphorous and phosphoric acid had the formulæ, P_2O_3 and P_2O_5. Baryta and the oxides of iron had the formulæ BaO, FeO, Fe_2O_3.

Such primary compounds were classified upon the same principle which served for the classification of the elements themselves, into electro-positive or basylous and electro-negative or chlorous compounds, and the smallest quantity of each of them, which consistently with an atomic representation of the results of analysis, was deemed capable of existing, was called an atom of that compound.

Very simple compounds possessed of prominent characteristics and distinct reactions had first been isolated and identified. They were found to contain their constituent elements in proportions easily recognisable as multiples of atomic weights. But such simple compounds are rare exceptions among mineral and organic materials, and if the atomic theory could have gone no further than to guide us to an understanding of these few simple compounds, it must soon have given place to some more fundamental conception. It is moreover worthy of notice that in this its most elementary form the atomic theory was not the only conceivable interpretation of the proportions of combination between elements. Those proportions could be as consistently represented by fractions as by integral multiples. Thus, instead of representing carbonic acid as containing twice as much oxygen as is contained in carbonic oxide, we might have represented it as containing the same quantity of oxygen combined with half as much carbon, and using for the moment atomic symbols for a non-atomic theory, we might have written carbonic acid thus $\frac{C}{2}O$. Or we might represent them both by percentage numbers.

It was so simple and natural to adopt the atomic hypothesis, and to represent compounds as built up of atoms, that chemists seem to have paid little attention to any other mode of representing the proportions of combination. They assumed that the variable proportions of elements, which were observed in compounds, were due to the various numbers of elementary atoms respectively aggregated together in each compound. They perceived that the existence of elementary atoms involved the existence of compound atoms, or molecules, as we now call them, and accordingly they represented each known compound of two elements by a molecular formula as simple as possible, consistently with the view of its atomic constitution. Many of these molecules, such as those of the acids, were found to be capable of combining with others of the other class, forming salts, and those combinations were found to take place in proportions corresponding to the weights of the respective molecules, or to very simple multiples of those weights, and the secondary compounds or salts thus formed combined (if at all) in proportions corresponding to simple multiples of their molecular weights. The dualistic representation of the constitution of salts served to represent the results of their analysis, consistently with the atomic theory, and a vast number of fundamental facts were collected and arranged by the aid of the dualistic theory of combination.

The actual numbers obtained by analysis of any particular compound exhibited sometimes a very near approximation to those required by an atomic formula of its composition. Sometimes they differed considerably from those required by theory; but it was always found that the more pure the substance and the more accurate the analytical operations, the more nearly did the result agree with some atomic formula of the substance.

The compound atoms were units which had grown out of the atomic theory. Each of them was the smallest quantity of a compound, which (consistently with the results of analysis) could be represented as built dualistically of its constituent atoms.

Chemical combination was viewed as a process of juxtaposition of simple or compound atoms, little account being taken of the disturbance of the previous arrangement of those compound atoms. It was when a constitution, similar to that attributed to salts, was imagined for other compounds not saline in their character, that the dualistic theory broke down. Thus chlorocarbonic acid was represented as a compound of carbonic acid with carbonic chloride, and was accordingly designated as carbonate of carbonic chloride, while the formula was made to contain the formulæ of those bodies. Chlorosulphuric acid and chlorochromic acid were in like manner represented as compounds of sulphuric and chromic acid respectively with imaginary hexachlorides.

Careful investigations of the reactions in which chlorocarbonic acid takes part showed, however, that in each of them it behaves as a compound containing only two atoms of chlorine. It was found that the commonest and best-known carbonates and sulphates have a fundamentally similar constitution. Thus potassic carbonate may be represented as a compound in which the two atoms of chlorine in phosgene are replaced by two atoms of the radical O K; and oil of vitriol, as a compound of two atoms of hydroxyl with the same group, $S\ O_2$, which in chlorosulphuric acid is combined with two atoms of chlorine. Chlorochromic acid has not been examined to as great an extent as the above compounds, but all we know of it points clearly to its having a molecular constitution similar to that of chlorosulphuric acid, viz. $Cl_2\ Cr\ O_2$, for not only do their vapour-densities agree, but the chromates in their constitution and crystalline forms exhibit a clear analogy to the sulphates.

Moreover, the simpler molecular formulæ, which a fuller knowledge of their chemical behaviour suggested for these bodies, were found in all cases to agree with the volume belonging to the molecule of every pure substance known in the state of vapour.

A difficulty of another kind had been foreseen by the great founder of the dualistic system, and it was by the investigations in organic chemistry that it assumed serious proportions.

Carbon compounds were discovered possessing definite and specific properties, and presenting the characteristics of pure substances, but of which the results of analysis did not agree with any simple proportion between the numbers of their constituent atoms. Their empyrical composition could not be decided by the aid of the so-called law of multiple proportions, for two or more atomic formulæ required percentages of the constituents differing so little from one another that analysis could not decide which was the true one.

In order to select the true molecular formulæ of such complex substances from among those which approached most nearly to the results of ultimate analysis, and to determine with certainty their empirical composition, it was necessary to find other methods for the determination of molecular weights. It was necessary to study the various properties of compounds of known composition, and of others which could be prepared in a state of purity; to determine the vapour densities and rates of diffusion of those which could be obtained in the gaseous state without decomposition; to determine boiling points and melting points; to examine crystalline forms of pure compounds and of mixtures; to determine solubilities and densities of solids and of liquids; but above all it was necessary to collect fuller and more accurate knowledge of the chemical changes which take place in the mutual reaction of molecules.

A vast amount of accurate and careful work of these kinds has been done, and has been subjected to rigid and often hostile scrutiny during the various stages of its progress. We now know that compound atoms, or molecules as we call them, which can be identified by their geometrical, mechanical, and other properties, are the same as the compound atoms indicated by the most comprehensive chemical evidences of composition and reactions. The molecular constitution of matter was predicted implicitly by the atomic theory of the constitution of the elements; and, wherever the physical properties of the molecules are such as afford any basis for the determination of their relative weights, such results agree with those derived from purely chemical considerations guided by the atomic theory.

Our knowledge of molecules is as yet in its infancy. Even among the commonest elements and compounds we know the molecular weights of very few, but what we do know of them proves that the idea of compound atoms invented by chemists to explain the elementary facts of chemical action is, as far as it goes, a true representation of what exists in nature.

Many of the molecules thus proved to exist were the same as those suggested under the dualistic system; but many were proved, by the more accurate and extensive knowledge of their reactions and properties, to have different weights from those which had been at first attributed to them, yet always consistent with the fundamental requirements of the atomic theory. Thus H_2O, CO, CO_2, CH_4, SO_2, SO_3, CaO, FeO, Fe_2O_3 are the formulæ still used to denote the molecules of the respective compounds, though the last three ought probably to be represented by some multiple. On the other hand, the molecule of olefiant gas is now represented by the formula C_2H_4, instead of CH_2. The chloracetate is $C_2Cl_3HO_2$, instead of C_2Cl_6, C_2O_3, H_2O. The molecule of benzoil chloride is C_7H_5OCl, instead of one corresponding to $(C_7H_5)_2O_3$, $C_7H_5Cl_3$, and chlorosulphuric acid is Cl_2SO_2, instead of $2SO_3$, SCl_6.

In proportion as chemists came to know more of the constitution of molecules, and to study chemical reactions from the point of view of the changes which they bring about in the constitution of molecules, did the idea of substitution come to be more and more used in the place of that of mere additive combination. A vast number of processes of chemical combination, which had been considered as consisting of direct combination, were found to be processes of double decomposition.

One of the most important facts which was brought to light by the careful examination of the composition of salts and organic bodies, aided by the molecular method of representing their constitution, was that hydrogen is chemically one of the metals, and that the compounds formed by the combination of water with acids are analogous to other salts of those acids; while compounds of hydrogen with elements or radicals like chlorine are salts, analogous in their constitution to other chlorides, &c.

The molecular or unitary mode of viewing the constitution of each substance affords more *true* as well as more simple records of the facts observed in chemical reactions than could be obtained in the dualistic systems. A salt such as hydric sulphate used to be considered as containing sulphuric acid and water, and represented by a formula such as SO_3, H_2O, implying the presence in it of both the substances from which it was known to be formed.

When two elements combined, their product was considered and described as containing the elementary atoms which had served to form it, and it was consistent with this habit to represent a product which had been formed by the combination of two compound molecules as containing those molecules.

But the main business of chemical investigation is to observe accurately the changes of composition which take place in the reactions of known substances, with a view of discovering the atomic interchanges to which they are due.

The compound formed by the combination of sulphuric acid and water differs in many physical and chemical properties from both of those bodies. Its name and its atomic formula serve to denote the aggregate of properties which are known to belong to it, whereas the dualistic formula, SO_3, H_2O, served to recall the properties of the acid and base from which it was formed, rather than those of the compound itself.

Elementary chemical reactions which according to the binary mode of viewing compounds were supposed to consist of dualistic processes involving sometimes the assumption of forces (like predisposing affinity) of a purely metaphysical character, were now explained as consisting of atomic displacements, or interchanges of a kind well known to be of common occurrence. Thus the evolution of hydrogen by the action of zinc on aqueous hydric sulphate was supposed to be the result of a decomposition of water by the metal, such decomposition being induced by the presence of the acid (SO_3), which exerted a predisposing affinity for the zinc oxide. Our present explanation is a simple statement of the fact, that under the conditions described, zinc displaces hydrogen from its sulphate.

The recognition and study of the metallic functions of hydrogen enabled chemists to obtain far clearer and simpler views of the constitution of salts, and to observe the differences of property which are produced in them by the replacement of one element by another. It enabled us to see more and more clearly the characteristic functions of each element, by comparing the constitution and properties of the salts containing it with those of the corresponding salts containing other elements.

Thus in the dualistic system we had for the three common phosphates, PO_4Na_3. PO_4Na_2H, PO_4NaH_2, molecular formulæ in which sodium was represented with twice as great an atomic weight as that which we attribute to it, and which in our atomic weights may be thus represented, viz. P_2O_5, $3Na_2O$; P_2O_5, $2Na, O$; P_2O_5, Na_2O. In like manner we had such a formula as P_2O_3, $2Na_2O$ (for the phosphite PO_3Na_2H), and for the hypophosphite PO_2NaH_2 we had a formula corresponding to P_2O, Na_2O.

Determinations of water of crystallisation and of chemically combined water proved that many of the compounds assumed on the dualistic system to exist are either not obtainable or have different properties and a different constitution from those which have been described. Thus we now know that the salts PO_4Na_2H, PO_4NaH_2, PO_3Na_2H, and PO_2NaH_2 cannot be deprived of the elements of water without undergoing a fundamental change of composition and of properties.

The atomic weights of the alkali metals and of silver were found to be half of those of the dualistic system, and an atom of one of these metals, in common double decompositions between their salts and hydrogen-salts, changes place with one atom of hydrogen.

Many products of the combination of known molecules were found to be formed by processes of double decomposition, so that each molecule of such products is built up partly of atoms derived from one of the materials, partly of atoms from the other. Thus potassic hydrate is formed by the combination of a molecule of potash with one of water. Yet each molecule of the hydrate is built up of half a molecule of potash and half a molecule of water.

The study of organic compounds played an important part in the improvement of our processes of reasoning. Many of their molecules having a very complex structure were found to undergo in most of their reactions very simple changes, of the same kind as those which mineral compounds undergo. Most of the elements of each organic molecule remained combined together with functions analogous to those of hydrogen or chlorine.

The theory of radicals which had been suggested by the reactions of ammonia-salts and of cyanides was largely extended in organic chemistry.

Many families of organic compounds were discovered in each of which the members are connected by close analogy of constitution and of properties. Each of these families forms what is called a homologous series, each term of the series being a compound of which the molecule contains one atom of carbon and two atoms of hydrogen more than the previous term.

Thus a series of compounds was proved to have reactions similar to those of common alcohol, and molecular weights ranging from 32 to 438. The lower terms of the series are distinguished from one another by differences of boiling points approximately proportional to the number of atoms of carbon and hydrogen by which they differ from one another; whilst the higher terms undergo decomposition at the high temperatures required for their evaporation, and are distinguished from one another by differences of melting points, that of the alcohol $C_{30}H_{62}O$ being about 85° C. In their constitution these alcohols were found to be analogous to the alkaline hydrates.

In like manner various other series of alcohols were discovered corresponding respectively in their constitutions to other classes of metallic hydrates. Series were also found of which the members present analogies of reaction with monobasic, bibasic, and tribasic hydrogen salts respectively.

These and many other such discoveries were made under the guidance of the atomic theory, developed to the point of systematically recognising and studying the mutual reactions of molecules.

One of the most remarkable and important extensions which our knowledge of molecules has undergone consisted in the discovery that various elements in what we are accustomed to consider the free state, really consist of molecules containing like atoms combined with one another.

Thus chemists adopt the formulæ O_2, H_2, Cl_2, P_4, J_2, As_4, to denote molecules of the respective elements, and we have for these molecular formulæ evidences of the same kinds as those which serve to establish the molecular formulæ ClH, H_2O, NH_3, &c. In all the best-known reactions in which chlorine or hydrogen are either taken up or evolved we find that those elements behave as chemical compounds of two like atoms; and, moreover, their molecules, as determined from a study of their reactions, have the same volume as that of every compound molecule proved to evaporate without decomposition.

With this knowledge of the molecular constitution of hydrogen and of chlorine gases, we come to regard the direct formation of hydric chloride as due to a process of double decomposition between two molecules, like the reaction of chlorine on an equal volume of marsh gas.

Many other reactions, such as the evolution of hydrogen by the action of zinc on a hydrogen salt, the liberation of chlorine and nitrogen on the explosive decomposition of their compound, the direct combination of oxygen and hydrogen, we may expect to be able to resolve into mere processes of double decomposition.

The earliest determinations of combining proportions were made with salts (hydrogen salts and others) which undergo double decomposition by mutual contact, and the term equivalent was subsequently introduced to indicate the proportional weights of analogous substances found to be of equal value in their chemical effects. Tables of equivalent weights of acids consisted of numbers standing to one another in the same proportions as the weights of the respective substances found to be of equal value in neutralising a fixed quantity of a particular base; and in like manner tables of the equivalent weights of bases recorded the proportions by weight in which certain bases might replace one another in the neutralisation of a particular quantity of a given acid. Similar determinations have been tabulated of the so-called equivalent weights of elements. Under the dualistic system chemists paid little attention to the essential difference between atomic weights and equivalent weights; and some were of opinion that the facts of chemistry might be represented as consistently from the point of view of equivalence as from that of atoms, and that the idea of atoms (which they considered to be hypothetical) might be dispensed with.

In the system of atomic weights employed under that system, two atoms of hydrogen were generally represented as reacting together, and the symbol of the double atom was marked thus, Ħ. The alkali metals and silver were represented as having atomic weights twice as great as those which we now adopt, and equivalent to those of the magnesian metals and of oxygen. In a great number of the common reactions of these elements the atomic symbols were consistently used as equivalent symbols. But those who professed to dispense with the atomic theory used atomic symbols, even in cases where they did not represent equivalent weights. Thus nitrogen was always represented by its atomic symbol, and the composition and reactions of nitrogen compounds were always studied and represented in accordance with the atomic theory, using various multiple proportions of what they were still pleased to call equivalent weights, using molecular weights, and various other ideas which formed part of the atomic theory, and which had no known connection with the notion of fixed equivalence. If, however, it be true that all chemical compounds consist of elementary atoms, and that the explanation of chemical reactions consists in stating more and more precisely the changes of combination between the constituent atoms of the reacting molecules; equivalence could only be said to exist between a like number of atoms when they were known to have similar functions. It became necessary to study the relation of equivalence between elementary atoms, instead of studying them from the point of view of elements divisible in any proportion.

It is worth while noticing the general process by which this intellectual change was brought about; for there is a good deal yet to be done in the matter, and our future progress may be guided by experience gained in the past.

It was essentially one-sided. One consideration was brought into very prominent relie', and it threw a marvellous light on the matter. It gave us a clear view of the natural order among elements; but, like every other strong light, it fell on one side only.

The equality of vapour-volumes had been used with great advantage in conjunction with chemical reactions and other evidence as a characteristic of molecules, and the attention of chemists was greatly arrested by the consideration of four typical compounds, which upon the concurrent evidence of very extensive chemical examination and equality of vapour-volumes were known to have respectively a composition corresponding to the formulæ ClH, OH_2, NH_3, CH_4.

It was known that the atom of oxygen in water can be replaced by chlorine, but that two atoms of chlorine are needed for the purpose. The atom of nitrogen in ammonia requires three atoms of chlorine to replace it, whilst in marsh gas the atom of carbon is replaceable by four atoms of chlorine. Other elements were studied from the point of view of their respective resemblance to these, and arranged in classes, each of which consisted of atoms equivalent to one another. Thus chlorine, bromine, iodine, fluorine, hydrogen, potassium, sodium, lithium, silver, &c., constituted a class of atoms of equal value, and were called monads. Oxygen, sulphur, selenium, tellurium, calcium, strontium, barium, magnesium, zinc, cadmium, mercury, lead, copper, &c., were classed together as dyads, having equal value amongst themselves, but double the atomic value of the members of the first class. So nitrogen, phosphorus, arsenic, antimony, bismuth, with boron, and some other elements, were considered as forming a class of atoms each of which has three times the value of the monads. The class of tetrads contained carbon, silicon, tin, platinum, &c.

Many apparent exceptions to these atomic values were satisfactorily explained as due to the partial combination of like atoms with one another. Thus in the vast majority of hydrocarbons, such as C_2H_6, C_2H_4, C_2H_2, &c., the atoms of carbon do not appear to be tetravalent, inasmuch as each of the molecules contains less than four atoms of hydrogen to every one atom of carbon. It was well known, however, that polyvalent atoms can combine partly with one element, partly with another, and also that like atoms can combine with one another. Why then should not two tetravalent atoms like carbon combine respectively with three atoms of a monad, and also combine with one another? The compound must be a single molecule with the properties known to belong to methyle $C_2\,H_6$. Again, if this molecule were deprived of two of its atoms of hydrogen, each of the atoms of carbon must combine further with the other atom of carbon forming $H_2\,C\,C\,H_2$; and a further step in this same direction would give us acetylene $H\,C\,C\,H$, in which each atom of carbon is combined with the other to the extent of three quarters of its value, and with one atom of hydrogen. An extension of this reasoning led to the discovery of long chains of atoms of carbon, each atom forming a link, and each of them (short of the ends) being combined with two other atoms of carbon, while its saturation is completed by hydrogen.

Similar partial combinations of like atoms with one another were recognised in many other classes of compounds, and there is strong reason to expect that the application of the principle will be far more widely extended in proportion as our knowledge of the silicates and other complex classes of compounds becomes somewhat definite.

This incorporation of the doctrine of equivalence into the atomic theory by the division of the elements into classes consisting respectively of equivalent atoms, was probably one of the most important general steps as yet made in the development of the atomic theory. It was seen to correspond in so clear and striking a manner with a vast number of well-known properties and reactions of compounds as to deserve and acquire the confident trust of chemists. But, as often happens in such cases, this confidence in the result carried many of them too far. It led them to assume that atomic values in all other chemical compounds must be always the same as in the compounds under consideration. They saw that they had got hold of the truth, and they thought it was the whole truth. For instance, one most distinguished chemist assumed that each elementary atom has only one value in its compounds; that the atom of nitrogen has always the value three, as in ammonia and its products of substitution, and that in sal ammoniac the atom of nitrogen is chemically combined only with three atoms of hydrogen, whilst the molecule of ammonia is in a state of molecular combination with hydric chloride. Another most distinguished chemist admitted that nitrogen and phosphorus have two atomic values, but not more than two. He held that the respective combining powers are always satisfied by the same number of atoms, no matter what the character of the uniting atoms may be.

With respect to these views it may be noticed that the assumption of combination between molecules as due to some other force than that which binds together the constituents of each molecule—in fact the assumption of molecular combination as an unknown something different from chemical combination, is open to even more grave objections than those which led us to abandon the dualistic system.

To represent a molecule of sal ammoniac as a compound containing two molecules, each one built up by the chemical combination of the constituent atoms, and the two united together by some other force called molecular, was hardly a step in advance of the view which represented it as containing two molecules united together by the same kind of force as that which holds together the atoms in each of the constituent molecules.

The other form of the theory of atomicity as an inherent property of each atom enabling it to combine with an equal number of other atoms, whatever the character of those other atoms may be, seems difficult to reconcile with such facts as the following: An atom of nitrogen is not known to combine with more than three atoms of hydrogen alone, or of substances like hydrogen, but it forms stable compounds with five atoms (as in the ammonia salts), when four of them are basylous and one of them is chlorous. An atom of sulphur is not known to combine with more than two atoms of hydrogen alone, but it forms stable compounds with four atoms, if three of them are like hydrogen, while the fourth is chlorous. Instances like these are plentiful, and they lead us to look to the chemical characters of the atoms bound together in one molecule as a fundamental condition of the atomic value of the element which binds them together.

Theoretical limitations of natural forces are very difficult of proof, and it is well to be slow and cautious in adopting any such limitation.

A careful consideration of the facts of the case has led me not only to doubt the validity of the supposed limits of atomic value, but to doubt whether we have grounds for assigning any limits whatever to such values.

Atomic values appear to me to be in their very nature variable quantities, and I venture to think that chemistry will be greatly advanced by a full and careful study of the conditions of variation of atomic values.

Two conditions of change of atomic value are particularly worthy of notice:—

I. Temperature.

II. The chemical character of the uniting atoms.

Atomic values increase with fall of temperature, and diminish with rise of temperature. An atom which is combined with as many basylous monads as it can take up by themselves will take up chlorous monads, or both chlorous and basylous, and reciprocally.

In illustration of the diminution of atomic values with rise of temperature, I may adduce the following well-known reactions: Sal ammoniac containing nitrogen combined with five monads breaks up at a high temperature into ammonia and hydric chloride; and in like manner other ammonia salts decompose by heat, forming ammonia or an amide, with trivalent nitrogen. The highest chlorides of phosphorus and of antimony are decomposed by heat into free chlorine and the lower chloride. Potassic fluosilicate is decomposed by heat into silicic and potassic fluorides; and carbonic acid breaks up at high temperatures into a mixture of carbonic oxide and oxygen.

Amongst illustrations of the greater atomic values which elements assume by combining with both chlorous and basylous atoms than with atoms of the one kind only we may take the following cases: Platinum is a metal of which the atom has been supposed to be always tetravalent, because it has not been found capable of combining with more than four atoms of chlorine. The common solution formed by aqua regia contains the compound H_2PtCl_6, a perfectly definite and crystallisable hydrogen salt. Chemists are constantly making and using the potassium and ammonium salts, &c., corresponding to it, yet they conceal from themselves the fact that the atom of platinum is directly combined with eight monads by calling the compounds double salts. The atom of silicon in the silico-fluorides such as H_2SiF_6 or K_2SiF_6 is combined with twice as many monads as it can take up of one kind; so boron in the crystalline salt $NaBF_4$ has a higher atomic value than in its fluoride, owing to the presence of the atom of sodium.

In like manner the atom of gold in the well-known salt $NaAuCl_4$ has a higher value than it can assume with chlorine alone.

Sulphur of which the atom does not combine with more than 2 atoms of hydrogen, forms with 3 atoms of methyle, or ethyle, and one atom of iodine, or chlorine, &c., the well-known compounds like $ISMe_3$; and iodine, which is considered a monad, forms the crystalline and stable periodate $OI(OH)_5$ and the various metallic derivatives, such as

$$OI\,\begin{matrix}ONa\\(OH)_4\end{matrix} \qquad OI\,\begin{matrix}(ONa)_2\\(OH)_3\end{matrix} \qquad OI\,(OAg)_5$$

The crystalline compound of the perchlorate with water ($HClO_4 2H_2O$) has probably a similar constitution. Chemical journals abound with descriptions of definite and well-characterised compounds, which have, like the above, been put aside by the atomicity theory, as mere molecular compounds. The following formulæ are taken almost at random, in illustration of the generality of atomic values far beyond those acknowledged by the theory of atomicity.

$IPCl_6$	K_2FeF_4	K_2SnCl_6
$KAsF_6$	$2(K_2FeCl_5)$	$KHgI_3$
K_2AsF_7	$2(K_3FeF_6)$	$K_2HgI_4 4H_2O$
$KSbF_6$	K_2CuCl_4	$KHgCl_3$
K_2SbCl_5	K_2CuF_4	K_2HgCl_4
K_2SbF_7	$KMgCl_3$	
K_2BiCl_5	K_2MgBr_4	
K_2AgI_3		

I have for convenience written in the middle of each of these formulæ the symbol of the atom which I assume to act as connecting element. If we consider the atomic values usually found in these elements together with those represented by the above list, we see that their atomic values vary according to the numbers given in a line with them respectively in the following table. It has yet to be proved that the atom of platinum is tetravalent in any known compound, for there is no sufficient evidence to show that platinic chloride has a molecular weight corresponding to the formula $PtCl_4$, instead of one corresponding to Pt_2Cl_8, each atom of platinum being partly combined with the other, partly with chlorine.

Atomic Symbols	Atomic Values
C	2, 4
S	2, 4
Pt	4 (?), 8
Si	4, 8
Sn	4, 8
Cu	2, 6
Hg	2, 4, 6
Mg	2, 4, 6
Ag	1, 5

Atomic Symbols	Atomic Values
B	3, 5
I	1, 7
N	3, 5
P	3, 5, 7
As	3, 7, 9
Sb	3, 5, 7, 9
Bi	3, 7
Au	3 (?), 5

Not only are there elements of which an atom is found in combination with a greater number of basylous and chlorous monads together than of either kind alone, but there are also elements which are not known to form chemical compounds with hydrogen or potassium alone, and yet which combine with either of them when also combined with chlorine, fluorine, &c. This is illustrated by the following compounds, viz. $HAuCl_4$, H_2PtCl_6, $NaBF_4$, K_2SiF_6, K_2FeF_4, K_2CuCl_4. It is also well known that there are many cases of elements of which an atom cannot combine with as many monads of one kind as of another. For instance an atom of nitrogen or of antimony is only known to be trivalent in combination with hydrogen; but each of them occurs in the form of a pentavalent compound with chlorine. Antimony forms either no compound with five atoms of bromine, or a compound more unstable than the higher chloride.

Many more such instances might easily now be given, and a vast number will doubtless be found when the investigations of chemists are directed to the search for them. I have only given these few by way of illustration of the leading conditions of change of atomic values.

In the course of their investigations of the precise interchanges of atoms which take place between molecules, chemists were frequently led to observe evidences of the order in which the constituent elements are combined; and with the more wide and accurate knowledge of reactions which is now in their possession, they have been enabled to follow up so far the study of the respective state of combination of each atom in a molecule as to arrive at simple and consistent explanations of facts which had previously eluded the grasp of science.

Our knowledge of the order of combination of atoms in a molecule and of the differences between direct and indirect combinations of particular atoms may be said to have originated chiefly in the study of the compounds of nitrogen. Thus it was found that the hydrogen in ammonia differs in many of its chemical functions from hydrogen in hydrocarbons. A base (called methylia) was discovered having a molecular composition corresponding to the empirical formula (CNH_5), and this base was found to contain two atoms of hydrogen like those of ammonia and three atoms like those in hydrocarbons. Its constitution was accordingly represented by a formula describing it as an ammonia, in which one atom of hydrogen is replaced by the monad methyle, or, to be more explicit, as containing two atoms of hydrogen directly combined with nitrogen, and three atoms of hydrogen indirectly combined with that same atom of nitrogen through the intervening atom of carbon. Writing in juxtaposition to one another the symbols of those atoms which are directly combined, we can express the facts by the following formula, viz. H_2NCH_3.

Those marvellous varieties of matter called isomeric compounds found their natural explanation in differences of the respective arrangements of like atoms. Thus two bases were discovered having the same empirical molecular formula, C_2NH_7. One of them is made by different reactions from the other, and in its decompositions differs from the other. All these chemical differences between them are found to be due to the fact that one of them (called ethylia) contains two atoms of hydrogen directly combined with the nitrogen, and the monovalent hydro-carbon ethyle in place of the third atom of hydrogen; whilst the other (called dimethylia) contains only one atom of hydrogen combined directly with nitrogen, the carbon of the two atoms of methyle completing the saturation of the trivalent nitrogen, as expressed by the formula $H\ N\ (C\ H_3)_2$.

It was subsequently proved that an atom of oxygen may combine with two like or unlike monads, such monads being indirectly combined with one another through the intervening atom of oxygen. Thus five of the atoms of hydrogen in common alcohol were proved to be in direct combination with the carbon, whilst the other one is indirectly combined with it through the oxygen, as expressed by the formula $HO(C_2H_5)$.

Another compound (called methyl-oxide) was proved to have the same empyrical composition, but very different properties and reactions, its constitution being explained by the formula H_3COCH_3.

Again, two compounds of distinct reactions and properties were found to have the same empirical molecular composition, C_2NH_3, and it was clearly proved that in one of them the two atoms of carbon are directly combined thus, $NCCH_3$, whilst in the other they are indirectly combined through the atom of nitrogen $CNCH_3$.

An immense amount of admirable work has been done of late years (especially in Germany) in working out the evidences of the atomic order of complex organic bodies, and in thereby obtaining a command of their reactions.

Evidences of the same kind have been obtained of the atomic arrangement of some few of the simplest inorganic bodies, and it is to be hoped that ere long chemists will recognise the importance of examining the constitution of salts with the aid of the principles established in organic chemistry.

The foundation is already laid by our knowledge of the constitution of such compounds as

$$HOH,\ HOK,\ HONH_4,\ HONO_2$$
$$HOPbOH,\ HOPbONO_2,\ \underset{O}{HOCOK},\ \underset{O_2}{HOSOH}$$

and there is a strong probability regarding the atomic constitution of many other water compounds, *e.g.* $SO_4H_2 + H_2O = OS(OH)_4$, $SO_5H_4 + H_2O = S(OH)_6$.

Amongst the extensions of our means of examining the physical properties of matter, and thereby discovering new varieties of matter for chemical investigation, spectrum analysis has played an important part, and is no doubt destined to do far more. It has already led chemists to the discovery of several previously unknown elements, and has led to the detection of various known elements in distant masses of which we had previously no chemical knowledge.

Up to this point the growth of the atomic theory will be seen, from the general outline which I have endeavoured to trace, to have consisted mainly in the more and more full and exact identification of each elementary atom, and in the accumulation of more and more varied and accurate evidences of its functions in relation to other atoms. A step was made towards a knowledge of the general relations of atoms to one another by their preliminary classification according to their best-known values.

But a far greater step has been more recently made, one which is evidently destined to lead to most important results.

It was discovered that if we arrange the elements in the empirical order of their respective atomic weights, beginning with hydrogen and proceeding thence step by step to the heaviest atom, we have before us a natural series with periodically recurrent changes in the chemical and physical functions of its members.

Of course the series is imperfect, and exhibits gaps and irregularities; but what view of natural order has been complete in its infancy?

Some of the gaps have already been filled up by the discovery of elements possessing the anticipated properties. The generalisation affords a brilliant addition to the previous corroborations of the reality of the units of matter which chemists have discovered.

Chemists have as yet taken but little account of atomic motion; although the most perfect explanation of a chemical reaction consists of a statement of the atomic interchange which takes place between two molecules; or the change of mutual combination between the atoms in one molecule.

It has, however, been proved that the heat of combination affords a measure of its force; and we know that in giving off heat particles of matter undergo a diminution of velocity of motion. We see, accordingly, that substances capable of exerting great force by their combination are those which can undergo a great diminution of the velocity of their internal motions, and reciprocally.

The force of chemical combination is evidently a function of atomic motion.

It has been shown that the relative velocities of certain atomic interchanges afford a measure of the amount of chemical action between two substances: but a vast amount of work will doubtless be required to develop the atomic theory to the point of explaining the force of chemical action in precise terms of atomic motion.

The general terms of chemistry are mere symbols. Each of them serves to recall a group (usually a very large group) of facts established by observation. The explanation of each term is afforded by a careful study of the facts which it is used to denote; and, accordingly, a chain of evidence involving the use of chemical terms can be fully understood only by chemists accustomed to the consideration of such evidence. The general outline of it may perhaps be to some general thinkers of sufficient interest to attract them to further study of our science.

---

4. *On the Chemical Action between Solids. By* Professor T. E. THORPE, *Ph.D., F.R.S.*

The author drew attention to the extremely rare instances of such action hitherto observed, showing how many of these might be explained on the supposition that combination actually occurred between the bodies, either in solution or in a state of gas. He illustrated his subject by experiments on the formation of several compounds by bringing together the components in their solid form, choosing as examples such as would manifest the change by characteristic colours. After a short reference to a memoir of Professor Spring, he said one of the most remarkable results obtained by the Belgian professor was the formation of coal from peat by subjecting the latter to high pressure. Peat from Holland and Belgium, when exposed to the pressure of six thousand atmospheres, was, according to Spring, changed into a mass which in all physical characteristics resembled ordinary coal. Experiments of the same kind were made by the author, but with a negative result.

---

5. *On the First Two Lines of Mendelejeff's Table of Atomic Weights. By* W. WELDON, *F.R.S.E.*

The object of this communication was to point out certain relations between the atomic weights of the fourteen elements occupying the first two lines of Mendelejeff's Table. The author showed that there is not one of these atomic weights some power of which is not a simple multiple of the corresponding power of the atomic weight of lithium.

---

6. *On the Occlusion of Gaseous Matter by Fused Silicates at High Temperatures, and its possible connection with Volcanic Agencies. By* I. LOWTHIAN BELL, *F.R.S.*

---

7. *On the Siliceous and other Hot Springs in the Volcanic District of the North Island of New Zealand. By* WM. LANT CARPENTER, *B.A., B.Sc., F.C.S.*

The writer had visited New Zealand in December 1880, and through the kindness of Dr. Hector, F.R.S., head of the Colonial Museum, had been put in possession of much information with regard to this remarkable district. From the active volcano Tongariro, in the centre of the North Island, three 'lines of fire' could be traced in a N.E. direction, ending at White Island, in the Bay of Plenty. Superficially the district consisted chiefly of post-tertiary sedimentary deposits and acid volcanic rocks. Lake Taupo, 248 miles' area, 1,250 feet above sea-level, but whose bottom was below sea-level, was the chief source of water in the whole region, and it had probably subterranean outlets.

Three classes of springs were considered:—

1. Near Lake Taupo.

2. In the famous 'Hot Lake District' of Rotorua and Rotomahana, where are unique siliceous terraces.

3. On White Island, in the Bay of Plenty.

I. The springs near Lake Taupo are all more or less siliceous, and remarkable for the presence of free iodine. They are medicinally useful. Particulars of ten springs were given, in five of which the silica was one-half of the total solid constituents; and in two more, one-third. The maximum here was 28·51 grains silica per gallon; total solids, 56·47 grains. Two contained respectively 40·5 and 56·1 grains chlorine (chiefly as sodium chloride), and 0·714 and 1·012 grains per gallon of free iodine. Another was so strongly charged with sulphates of iron and alumina as to taint a river therewith for seventy miles, its whole course.

II. Hot Lake District:—

On the shores of Lake Rotomahana were two wonderful siliceous terraces, formed by the deposition of silica from two intermittent boiling springs, of the following composition, according to the Colonial Laboratory reports:—

	White terrace	Pink terrace
Monosilicate of soda	68·48	—
„ lime	1·62	1·91
„ magnesia	0·53	1·16
„ iron	0·51	—
Silica, free	—	43·95
Chloride of potassium	2·87	1·05
„ sodium	62·61	93·55
Sulphate of lime	—	10·96
„ soda	7·84	1·01
Alumina (as phosphate)	traces	0·54
Iron oxides	—	traces
Grains per gallon	144·46	154·13

The writer had brought home a specimen of the siliceous sinter, and carefully analysed it, with the annexed result:—

Water expelled by red heat	9·67 per cent.
Salts soluble in water, almost entirely sodium silicate	0·59 „
Anhydrous silica	87·35 „
Lime, soda, and alumina, by difference, but all detected	2·39 „
	100·00 „

No chlorine could be discovered in it, though there was so much in the water whence it was derived. It was also quite free from iron.

Of fifteen springs in this district, five contained silicate of soda, and twelve free silica. Chloride of sodium was present in eight. Lime-salts only amounted usually to two or three grains per gallon. Free hydrochloric acid was found in eight, always with free silica, and six of these eight contained free sulphuric acid (one as much as 77 grains per gallon).

III. White Island springs.

This island is the summit of an extinct volcano, whose crater is occupied by a lake of strong mineral water, fed by intermittent geysers and boiling springs, and containing more than 10,000 grains per gallon of free hydrochloric acid. All the springs deposited sulphur and sulphate of lime. Annexed are the analyses:—

	Lake Hope	Fumarole
Sulphate of iron	1163·980	23·573
„ soda	680·325	9·240
„ potash	297·124	a trace
„ lime	251·682	115·933
„ magnesia	66·312	29·120
„ alumina	87·668	a trace
„ ammonia	—	a trace
Carried forward	2547·091	177·866

	Lake Hope	Fumarole
Brought forward . . .	2547·091	177·866
Sesquichloride aluminium	1870·085	—
Silica, uncombined	23·628	9·013
Sulphurous acid	—	a trace
Phosphoric acid	—	a trace
Sulphuric acid, free	—	11·933
Hydrochloric acid, free . . .	10409·589	9·706
Grains per gallon . . .	14850·393	208·518

FRIDAY, SEPTEMBER 2.

The following Report and Papers were read:—

1. *Second Report of the Committee upon the present state of our Knowledge of Spectrum Analysis.*—See Reports, p. 317.

2. *On the Fluid Density of certain Metals.* *By* Professor W. CHANDLER ROBERTS, *F.R.S., and* T. WRIGHTSON.

3. *On the Oxides of Manganese.* *By* V. H. VELEY, *B.A.*

The author at the outset gave an historical account of researches on the oxides of manganese, in order to show how far it has been satisfactorily proved by them, firstly, that manganese forms with oxygen a series of definite oxides (apart from those present in manganic and permanganic acids), and secondly, that manganese dioxide forms a series of hydrates. The researches of Dittmar, Wright, and others, on the conditions of formation of these oxides, and their behaviour when heated to various temperatures in certain gases, is also noticed.

The author had studied the action of air, oxygen, nitrogen, and hydrogen at temperatures ranging from 60° to 200° C. on an oxide of formula Mn_6O_{11}, and has prepared and analysed the following higher oxides and hydrates.

	$Mn_{24}O_{44}8H_2O$	$Mn_{24}O_{45}8H_2O$(?)		
	$Mn_{24}O_{44}6H_2O$			
	$Mn_{24}O_{44}4H_2O$		$Mn_{24}O_{46}3H_2O$	
$Mn_{24}O_{32}3H_2O$	$Mn_{24}O_{44}2H_2O$		$Mn_{24}O_{46}2H_2O$	$Mn_{24}O_{47}2H_2O$

When the oxides are heated in air or oxygen at low temperatures two changes are observed: 1st, a loss of water of hydration; 2nd, an absorption of oxygen. When heated in nitrogen they are dehydrated; but do not, as at higher temperatures, lose so-called available oxygen. When heated in hydrogen they are simultaneously dehydrated and reduced. The author inclined to the view that these oxides are distinct chemical entities, and are not mere combinations of molecules (molecular compounds). The author is carrying on further researches on the oxides of manganese in order to study more completely the conditions of formation, of temperature, tension of oxygen and other gases of each separate oxide and hydrate; and hopes thereby to arrive at a more intimate knowledge of the constitution of the metallic oxides.

4. *On the Inferences deducible from high Molecular Weights, as exhibited by the Oxides of Manganese.* *By* Professor W. ODLING, *F.R.S.*

5. *On Manganese Nodules, and their Occurrence on the Sea-bottom.* *By* J. Y. Buchanan.

The specimens exhibited consist of two nodules from the South Pacific and of several from Loch Fyne in Scotland, a number of manganiferous worm-tubes and two samples of the mud in which these tubes and nodules are found in Loch Fyne. I have besides some very curious specimens of cobalt nodules from New Caledonia, which I owe to the kindness of my friend Professor Liversidge, of the University of Sydney. These have come into my hands only within the last few days and I exhibit them as curiosities which may have an interest for some of the members present.

My method of dredging for mud consists in anchoring the vessel by a dredge in the form of a Trotman's anchor, which carries a frame instead of a bar connecting the flukes. To this frame is lashed a bag which receives the mud which might otherwise drop off the anchor on heaving up. This method has proved successful in two ways: first, by keeping the vessel stationary while the anchor is down, and so admitting of temperature-observations being made and water samples being collected without having to resort to troublesome manœuvres; and, secondly, by bringing up a large specimen of the mud taken, not from the soft surface layer, as is the case with the flat dredge, but from the underlying and stiffer material.

My first and best haul of manganese nodules, however, was brought up on an ordinary kedge anchor and adhering to its flukes. A portion of this mud is exhibited. It is from the deepest part of Loch Fyne, between Tarbert and Skate Island. It was described in 'Nature' of October 10, 1878. I have never succeeded in getting mud so rich in nodules again. Part of it when sifted was found to consist of 30 per cent. manganese nodules, 7·5 per cent. shells, and 62·5 per cent. of sandy clay. I doubt very much if even the richest bottom in the Pacific contains a like proportion. The other two samples of nodule-bearing mud are, as nearly as possible, from the same locality; but though they contain plenty of nodules, these nodules are of a smaller average size, and are present in much smaller proportion to the rest of the mud. Of the nodules collected on the first occasion, in 1878, the average weight was 1·7 grammes; of those collected last July the average weight, after eliminating all that passed through a sieve of four meshes to the inch, was only 0·42 grammes, and the proportion of nodules to mud would certainly not be more than 5 per cent. The whole of the mud which came up on this occasion was sifted, with the exception of a small sample dried as it was; the nodules were then sorted by sieves of different degrees of fineness. The bulk of them were retained by a $\frac{1}{4}$-inch mesh. The nodules so retained weighed 307 grammes, and numbered 726, and it is remarkable that besides these nodules there was nothing on the sieve but a few fragments of shell and *two pebbles.* This affords very strong evidence that the nodules are formed *in situ*, and cannot have been washed into their present position, as in that case they would certainly have been accompanied by pebbles.

Hitherto the deep portion of Loch Fyne above alluded to is the only locality in Scottish waters where I have found the oxide of manganese occurring as nodules. It is, however, widely distributed, encrusting shells and as worm-tubes, notably in the channel between Garvelloch Islands and the Island of Scarba and in Loch Sunart. Similarly during the cruise of the *Challenger*, besides the many localities where the nodules abounded, it was constantly found encrusting shells in calcareous bottoms which were devoid of nodules.

The Loch Fyne nodules resemble the oceanic ones in nearly every particular. They are comparatively soft when first brought up, and become harder when exposed to the air. Heated in the closed tube they give off water charged with ammonia and empyreumatic products. When treated with hydrochloric acid the soluble constituents are removed, and what remains behind includes the insoluble constituents of the surrounding mud. Many of the Loch Fyne nodules have soft kernels, which are richer in oxide of manganese than the rinds.

A considerable number of determinations have been made, both of the available oxygen and of the manganese; and if the manganese found be united to the whole of the available oxygen, the resulting formula varies between $MnO_{1\cdot5}$ and $MnO_{1\cdot6}$. Taking the soft kernel alone, separated from the more sandy rind, the formula is $MnO_{1\cdot75}$. The rind alone had the formula $MnO_{1\cdot5}$. In some oceanic nodules which were examined, the formula varied from $MnO_{1\cdot90}$ to $MnO_{1\cdot95}$.

Some of the mud which contained the Loch Fyne nodules was examined. It contained 0·71 per cent. of MnO, and a hardly distinguishable trace of extra oxygen.

If we express the available oxygen in terms of its equivalent MnO_2 we have in oceanic nodules from 22 to 32 per cent., in Loch Fyne ones from 13 to 22, and in the kernel treated separately 33 per cent. of MnO_2.

The insoluble residue varies in oceanic nodules from 16 to 30 per cent., and in the Loch Fyne ones from 28 to 33 per cent., both containing from 83 to 88 per cent. of silica.

Oceanic nodules appear to contain more nickel and cobalt than the Loch Fyne ones, while the latter contain distinct traces of copper, which does not appear to be so common in the oceanic ones.

With regard to the method of formation of these nodules, and the deposition of higher oxides, not only of manganese but of iron, on the sea-bottom, it is perhaps unwise at the present moment to speak positively; but I think there is enough known to enable us to indicate a probable process of production.

All the nodules without exception contain residues of organic matter; where the oxide of manganese is not aggregated into nodules, it is found encrusting animal remains, as shells, worm-tubes, &c. Whether in the form of nodules or incrustations, the black matter contains all the recognisable sand and other matter of the surrounding mud; moreover, they are certainly formed *in situ*, and not brought from a distance. The mud in Loch Fyne, at any rate, contains manganese in the form of protoxide, and no doubt as silicates; it also contains oxides of iron, which are present in all manganese nodules and incrustations; indeed in the same dredgeful we can pick out all gradations of nodules, from those which contain almost exclusively MnO_2, with only traces of Fe_2O_3, to those which contain Fe_2O_3, without any MnO_2.

The formation of the sesquioxide of iron nodules has gone on under my own eyes. In July 1879 I dredged from the bottom of the Sound of Jura, in 70 to 80 fathoms, a large mass of very stiff blue clay, as stiff as the best brick-making clay. Throughout the mass there were disseminated patches and pockets of blackish blue matter which proved to be sulphide of iron; hydrochloric acid liberating sulphuretted hydrogen in abundance. This was dried in the usual way, in plates on the cylinder covers of the engine, and when dry not a trace of sulphide was to be found, every black patch being now represented by a reddish-brown one, even in the centre of large and compact masses. Now, what has here taken place in a very short time, under the combined action of air, moisture, and heat, takes place as surely, but more slowly, in the surface layer of the mud at the bottom; and, in point of fact, not only in our shallow seas, but even in the deepest water of the ocean, we find the surface layer of the mud almost invariably of a different colour from the underlying mass, the top being red while below the mud is grey. I believe, then, that for the formation of the nodules we have to look to the organic world as a necessary though indirect assistant. The decomposition of animal matter in presence of the sulphates of the sea-water, reduces these to sulphides, which in their turn react on the iron and manganese minerals (principally silicates) in the mud, forming sulphides of these metals. As the organic matter gets exhausted, these sulphides are oxidised to oxides by the oxygen of the water, forming concretions or incrustations of the ochreous oxides, which naturally also enclose the other and unaltered constituents of the mud.

In conclusion, I cannot help thinking that the shell-producing animals of the sea obtain the lime from the sea-water in this way, the lime being assimilated, from the dissolved sulphate, in the form of sulphide in the interior of the animal, and transformed into carbonate on the outside.

6. *On Brewing in Japan.*
By Professor R. W. Atkinson, *B.Sc.* (*Lond.*).

The Japanese brewing process is divided into two parts, comparable with the malting and brewing processes of beer-making. The preparation and properties of the diastatic material are, however, different, for whilst malt-extract hydrates cane-sugar, dextrin, and starch, the Japanese *kōji* hydrates maltose in addition, so that the ultimate products of its action upon starch-paste are dextrose and dextrin, or even the former alone. It further differs from malt in the fact that its solution is rendered inactive by heat at a lower temperature, about 70° C., and also by the manner of its formation. Unlike malt, the active properties of *kōji* are not due to the growth of the embryo, because the embryos are broken away by rough treatment, but by the growth over the steamed and cooled grains of rice of the mycelium of a fungus, the result of which is to burn away a good deal of the carbon and hydrogen of the rice, much heat being liberated, and to render soluble the previously insoluble albuminoid matter.

The brewing process proper is divided into two stages, the first stage being intended to prepare an actively growing yeast, the germs of which are sown spontaneously in the mash. A mixture of steamed-rice, *kōji,* and water is allowed to remain in shallow tubs at a low temperature (0°–5° C.) until quite liquid, after which it is heated, fermentation setting in immediately and continuing until nearly all the dextrose first formed is exhausted. This product is now used like yeast, and is added to fresh quantities of steamed-rice, *kōji,* and water, fermentation proceeding actively until the percentage of alcohol amounts to about 13 or 14 per cent. by weight. The conversion of starch into sugar and of the latter into alcohol go on concurrently, the diastase of the *kōji* transforming the starch throughout the whole process. After the greater part of the rice added has been used up the mash is filtered, clarified by standing, and when summer approaches, and signs of putrefactive fermentation appear, the *saké* is heated in iron vessels, an operation which preserves it for a time. No precautions being taken against the reintroduction of disease-germs, the heating process must be repeated about once a month throughout the summer.

Analyses of various specimens, fresh and diseased, are given in the paper.

---

7. *On Peppermint-camphor* (*Menthol*) *and some of its Derivatives.*
By Professor R. W. Atkinson, *B.Sc.* (*Lond.*), *and* H. Yoshida.

Determinations of some of the physical constants of menthol, menthone, menthene, and a hydrocarbon obtained by the action of hydric iodide upon menthol, with subsequent decomposition by caustic soda and metallic sodium, have been made.

Menthol.—$C^{10}H_{20}O$. Melting point, 42·2°C. Solidifying point, 40·3°C. Boiling point, 212°C. (corr.). Optical activity, determined from solutions in alcohol (96%), chloroform, benzene, and carbon disulphide, was found to be $-59·92° \pm 0·2$. The number obtained for its optical activity in glacial acetic acid was much lower *i.e.* $-54·28°$. All the above values express the specific rotatory power of menthol, independent of solvents. Menthol regenerated from its ketone has a specific rotatory power in alcohol solution $-39·66°$.

Menthone.—$C^{10}H_{18}O$. This body stands to menthol in the same relation that camphor stands to borneol. It is a clear, colourless liquid, boiling at 206·3° C (corr.) Its specific rotatory power is $+21·16°$. Its specific gravity at 0°C. is 0·9126, and the specific gravities and volumes at higher temperatures are given in the paper. The molecular refraction was found to be 75·3, that calculated from Brühl's numbers (carbon singly united) being 75·11.

Menthene.—$C^{10}H_{18}$. This boils at 167·4° (corr.). Its specific gravity at 0°, $D^0_4 = 0·82266$, and the specific gravities at temperatures up to 60°C. are given in the paper. The specific rotatory power is $[\alpha]_j = 13·25°$. The molecular refraction was found to be 74·045, which indicates that two carbon atoms are doubly combined, the calculated number in that case being 73·82. Menthene combines with fuming hydric chloride, forming a slightly yellow oil, $C^{10}H_{19}Cl$.

Hydrocarbon.—$C^{10}H_{16}$. This is the principal product found by cohobating menthol with a strong solution of hydric iodide, boiling with caustic soda, and finally digesting with sodium. It boils at 168·6° (corr.), but analysis showed that it still retained traces of menthene, which appears to be found in the same reaction. The specific gravities and volumes at different temperatures are given in the original paper, the specific gravity at 0° being 0·8263. The specific rotatory power was 5·2° for the transition tint. The molecular refraction was 73·28, the calculated value for four atoms of carbon doubly combined, being 73·24.

Remarks are made upon the difficulties met with in determining the specific volumes of the above compounds, and the paper concludes with a discussion of the probable constitution of menthol and its derivatives, in which the resemblance between camphor and menthone is pointed out.

---

8. *On the Sodium-alum of Japan. By* Professor EDWARD DIVERS, *M.D.*

The mineral sodium alum, since called Mendozite, was described by Thomson in 1828, as occurring in South America (St. Juan, near Mendoza). Its occurrence has not been noticed elsewhere.

Rammelsberg ('Mineral. Chemie') gives a series of percentages as obtained by Thomson, and refers them to an alum with twenty molecules of water. Dana ('System of Mineralogy') gives a different series as obtained by Thomson, and refers them to an alum with twenty-two molecules of water.

My late assistant, Mr. J. Mori, once a pupil of the Royal College of Chemistry, South Kensington, analysed the specimen I have now to describe, and obtained the following results:—

	Found	Calculated for Al_2O_3, Na_2O, $4SO_3$, $24H_2O$
Alumina	11·27	11·23
Soda	7·26	6·76
Sulphuric Oxide	34·73	34·90
Water	46·74 (by diff.)	47·11
	100·00	100·00

The soda is too high, else the results are most satisfactory, but error in excess here is probable from imperfect ignition to expel ammonium sulphate. Thomson found 7·96 soda, whereas for 22 Aq. alum only 7·1 are required. Potash is absent and only traces of iron, calcium, and insoluble matter are present.

Sodium-alum, therefore, occurs in nature of the normal type, with twenty-four molecules of water.

It occurs as an efflorescence on decomposing sodium (albite) felsite, with pyrites scattered through it. It is found in the province of Idzumo, in the prefecture of Shimané, Japan, not far from the coast. Like that examined by Thomson, it is not produced by a *solfatara*, though Shimané, like many parts of Japan, includes such. The alum is said to be obtainable in considerable quantity; but as a second parcel forwarded to me was damaged in transit by the leakage of bottles of natural alum-water I have only been able to examine very small specimens as yet.

It occurs in two forms—one massive, finely fibrous, greyish white, translucent; and also in friable opaque tears, slightly coloured by iron hydrate or oxide.

---

9. *On the Occurrence of Selenium and Tellurium in Japan. By* Professor EDWARD DIVERS, *M.D.*

At the sulphuric acid works of the Imperial Japanese Mint, and at a private establishment, both in Osaka, the sulphur now employed comes from different parts of Japan—Kagoshima, Oïta, Hokkaido, &c. In some of the sulphuric acid made there, I have found not inconsiderable quantities of selenium, and Mr. M. Shimosé, one of my pupils, has also found more than traces of tellurium. Arsenic is also present in quantity.

A former pupil of mine, Mr. Nakagawa, now a chemical engineer in the Imperial Mint, states that the flue-deposits of the sulphur burners are rich in selenium.

I had hoped to have obtained by this time fuller particulars, but have been disappointed by not receiving in time supplies of acid and flue-dust. I must, therefore, limit my communication to the announcement of the presence of these two elements in Japanese sulphuric acid, and of the probable occurrence of material quantities of selenium in Japan. A further communication will be published when particulars have been ascertained.

---

10. *On the Chrome Iron Ore of Japan. By* Professor Edward Divers, *M.D.*

The serpentine rocks of Japan, like those found elsewhere, contain small quantities of chrome iron oxide; but a few years ago masses of this mineral were sent from Oïta prefecture (Bungo) to the Tôkiyô Industrial Exhibition, and its nature then recognised. It has lately been analysed in the laboratory of the Imperial College of Engineering, Tôkiyô, by my former pupil, Mr. T. Haga, now one of the instructors in chemistry in the College.

It is massive, has a specific gravity 4·50, and a hardness 5·5, and is of a grey-black colour without any shade of brown, except where weathered. Its fracture is partly slaty, partly crystalline, showing numerous large faces inclined at all angles. Its lustre is resinous to sub-metallic, so that in appearance it is much like coal. Its powder is brown. Besides brown and green coatings on the faces of natural fractures in the mass, there are many small deposits of a greyish pink, but nearly white, soft and unctuous mineral. The behaviour of this chrome iron oxide to heat, presents nothing needing to be recorded, beyond that it slowly *gains* in weight. It contains only traces of magnetic matter.

Reduced to very fine powder and heated for three hours with hydrochloric acid, 2·53–2·87 per cent. dissolve, which together with some of the silica in the ore, make perhaps 4 per cent. decomposed. The soluble part has been separately analysed. An analysis of the soft white matter has also been made, but the portion of this which could be got was very small, and largely mixed with the chrome iron oxide. The following are the results of analyses:—

1. *The whole ore, air-dried.*

	I.	II.	Mean
Chromic oxide	59·39	59·20	59·30
Ferrous oxide	28·32	28·22	28·27

Chrome iron oxide	87·30	
Magnetite	0·29	
Magnesia	9·17	(9·10–9·24)
Silica	1·58	
Alumina	0·80	(0·82–0·78)
	99·14	

This leaves 0·88 for water (undetermined because of the difficulty arising from the already noted absorption of oxygen), additional oxygen if present, and other substances which may have escaped detection.

2. *The part decomposed by hydrochloric acid.*

	I.	II.	Mean
Chromic oxide	0·32	0·38	0·35
Iron oxide (if ferric)	0·53	0·55	0·54
Magnesia	1·17	1·44	1·30
Alumina	0·51	0·50	0·51
Silica (assumed as)	—	—	1·30

Part at least of the iron dissolved in the ferrous state. The residual ore still yielded traces of soluble matter to fresh acid.

3. *The pinkish white mineral.*

After allowing for 36·5 per cent. of admixed chrome iron oxide.

Silica	32·6
Magnesia	28·7
Alumina with a little ferric oxide	27·4
Water (loss on ignition)	11·3
	100·0

This analysis was made by Mr. Kawakita, another of the instructors, in the unavoidable absence of Mr. Haga.

The tabular statement of the composition of the ore shows that it is in almost exact agreement with that of pure ferrous chromite, as regards the ratio of iron oxide to chromium oxide. No such pure ore has hitherto been recorded as occurring, I believe, unless possibly in the papers of Christomanos, which I have only seen in abstracts. The insolubility of the iron in acids, and its non-magnetic character, prove that it is really combined as chromite. There remains the magnesia to account for. This cannot be in the free state, for not only is the occurrence of free magnesia in nature unknown and improbable, but in this mineral the magnesia, like the iron oxide, is for the most part insoluble in acid. From the abstracts ('Journ. Chem. Soc.,' xxxii.) of his papers, I learn that Christomanos in one paper asserts that pure chromite is always $FeCr_2O_4$, and all other constituents of the ore part of the matrix, and in another paper admits the existence of compounds of ferrous oxide with chromic oxide in three proportions, other than that of the ordinary spinel type. I see nothing for the case of the Oïta ore but to accept the view that the magnesia is a chemical part of it, the proportion of which, after deducting soluble magnesia, is almost exactly that required by the formula, MgO, 2FeO, $2Cr_2O_3$, corresponding to the 3FeO, $2Cr_2O_3$ of Christomanos.

	Found	Calculated for MgO, 2FeO, $2Cr_2O_3$
Almost insoluble—		
Chromic oxide	59·30	59·30
Ferrous oxide	27·90	28·00
Magnesia	7·93	7·78
	95·13	95·08
Soluble and silica—		
[Above magnes. ferr. chromite (about)	0·57]	
Hydrous magnes. alum. silicate	3·62	
Magnetite	0·29	
	99·04	

The visible presence of the white mineral, and the magnetic character of a very minute part of the powdered mineral, serve to confirm the propriety of the above arrangement.

The estimation of chromium and iron was made by the usual volumetric methods. To bring the ore into a soluble condition, Dittmar's method was employed, this method being very satisfactory, and, in Mr. Haga's hands, much easier than described in Dingl.

Fused borax, 2 parts, and dry potassium sodium carbonate, 3 parts, were fused together in a platinum crucible till effervescence ceased, and the whole cooled. About 1 part of very finely-powdered ore was then placed on the top, and the crucible covered and slowly heated to fusion. When the powder had become moistened with the melted flux, the lid was removed and the crucible kept at a red heat by a Bunsen flame. The liquid mass was occasionally stirred with a small platinum spatula. When particles of ore were no longer visible in the mass adhering to the spatula, the heat was maintained for only a few minutes longer, and the crucible then quickly cooled, to favour the detachment of the mass. One hour was sufficient for one gram of ore, and half-an-hour for half a gram. In this time, indeed, all the chromium may not have become chromate, but it will be all soluble in acid. Should the time have been too short, particles of ore will be visible in the bottom of the fused mass after removal from the crucible, and the mass must then be replaced and again heated. Unless the time of heating has been prolonged, it is safer to dissolve all up in sulphuric acid, oxidise with a few drops of permanganate solution any unoxidised chromium salt, and remove excess of permanganate by sodium carbonate and alcohol. A temperature for fusion so high that the crucible becomes attacked by the fluxes is quite unnecessary.

SATURDAY, SEPTEMBER 3.

The Section did not meet.

MONDAY, SEPTEMBER 5.

The following Papers were read:—

1. *On certain Points in Modern Progress in Chemical Knowledge. By* Professor H. E. Armstrong, *Ph.D., F.R.S.*

---

2. *On the alleged Decomposition of the Elements. By* Professor Dewar, *M.A., F.R.S.*

---

3. *On the Production of Crystals by the Action of Metals in Carbon Disulphide in Sealed Tubes. By* Philip Braham, *F.C.S.*

The mode in which the experiments were conducted was by sealing up fifteen different metals in carbon disulphide, and carefully examining them with the microscope. The tubes exhibited were put up on June 20, 1879, examined on June 20, 1880, and in May, 1881, transparent crystals were found in those which contained gold, antimony, and bismuth.

---

4. *On the Separation of Hydrocarbon Oils from Fat Oils.*[1] *By* Alfred H. Allen, *F.C.S.*

The extensive production of various hydrocarbon oils suitable for lubricating purposes, together with their low price, has resulted in their being largely employed for the adulteration of animal and vegetable oils. The hydrocarbons most commonly employed for such purposes are—

1. Oils produced by the distillation of *petroleum* and bituminous *shale,* having a density usually ranging between ·870 and ·915.

2. Oils produced by the distillation of common rosin, having a density of ·965 and upwards.

3. Neutral *coal-oil*; being the portion of the products of the distillation of coal-tar boiling at about 200°C., and freed from phenols by treatment with soda.

4. *Solid paraffin*; used for the adulteration of bees' wax and spermaceti, and employed in admixture with stearic acid for making candles.

The methods for the detection of hydrocarbon oils in fat oils are based on the *density* of the sample; the lowered *flashing* and *boiling* points; the *fluorescent character* of the oils of the first two classes; and the *incomplete saponification* of

[1] Published in full in the *Chemical News,* vol. xliv. p. 161.

the oil by alkalies. The *taste* of the oil and its *odour* on heating are also useful indications.

If undoubtedly fluorescent, an oil certainly contains a mixture of some hydrocarbon; but the converse is not strictly true, as the fluorescence of some varieties of mineral oil can be destroyed by chemical treatment, and in other cases fluorescence is wholly wanting. Still by far the greater number of hydrocarbon oils employed for lubricating purposes are strongly fluorescent, and the remainder usually become so on treatment with an equal measure of strong sulphuric acid.

The best and most accurate method of detecting hydrocarbon oils in, and quantitatively separating them from, fat oils, is to saponify the sample and then agitate the aqueous solution of the soap with ether. On separating the ethereal layer, and evaporating it at or below a steam heat, the hydrocarbon oil is obtained in a state of purity. The agitation with ether must be repeated several times to effect a complete extraction of the hydrocarbon oil from the soap solution.

The author has proved the accuracy of this process when applied to various mixtures of fat oils with hydrocarbon oils. The results obtained are correct to within about 1 per cent. in all ordinary cases. In cases where extreme accuracy is desired it is necessary to remember that most, if not all, animal and vegetable oils contain traces of matter wholly unacted on by alkalies. In certain cases, as butter and cod-liver oil, this matter consists largely of cholesterin. The proportion of unsaponifiable matter soluble in ether, which is naturally present in fixed oils and fats, rarely exceeds $1\frac{1}{2}$ per cent., and is usually much less. Sperm oil, however, constitutes an exception, yielding by the process about 40 per cent. of matter soluble in ether, the nature of which is undergoing further examination.

The following table indicates the general behaviour of the constituents of complex fats, oils, and waxes, when the aqueous solution of the saponified substance is shaken with ether:—

Dissolved by the Ether.	Remaining in the Aqueous Liquid.
Hydrocarbon oils, including	Fatty acids } In combination with the alkalies used.
Shale and Petroleum oils	Resin acids } In combination with the alkalies used.
Rosin oil	Carbolic and Cresylic acids } In combination with the alkalies used.
Coal-tar oil	*Glycerol* (glycerine)
Paraffin wax and ozokerite	
Vaseline	
Neutral resins	
Unsaponified fat or oil	
Unsaponifiable matter, as cholesterin	
Spermyl alcohol, from sperm oil	
Cetyl alcohol, from spermaceti	
Myricyl alcohol, from bees' wax	

The hydrocarbon oil, having been duly isolated by saponifying the sample and agitating the solution of the resultant soap with ether, may be further examined by observing its density, taste, and smell, behaviour with acids, &c.

---

5. *On some Phenomena which appear to be of the Nature of Chemico-Magnetic Action.* By William Thomson, *F.R.S.E.*

Some time ago I observed that the colour of a piece of prussian-blue cloth had been discharged in the vicinity of a piece of iron which was lying in contact with it, and thinking this action to be of the nature of magnetic, I made some experiments to learn something respecting it. I laid a piece of glass on a piece of wet prussian-blue cloth, and left it there for many weeks; the effect was that the cloth under the glass had apparently become rather darker in colour than the original cloth, but of this I was not quite certain, whilst the uncovered cloth was slightly bleached. The same effect was produced by laying a sheet of platinum on the wet blue cloth, and no blue colour was communicated to the wet blotting-paper on which they lay. These experiments proved that the colour of the cloth was not influenced by capillary action.

Small pieces of iron were laid on pieces of the prussian-blue cloth, with the result that the colour of the cloth on each side of the pieces of iron was completely discharged, and the colour so abstracted was arranged in deeply coloured lines, running in a semicircle from each end of the iron, and surrounding the semicircles of bleached cloth on each side of the bar. When the blue cloth with the piece of iron on it rested on several folds of wet blotting-paper, the insoluble blue colouring matter was distributed on and through the blotting paper in lines which were more distinct and delicate than those on the cloth itself. These lines of colour were evidently formed under the influence of some force of the nature of magnetism.

Small horse-shoe magnets were laid on the wet blue cloth, resting on wet blotting-paper, and well-curved lines of colour, usually more or less circular, were developed from the poles and from other parts of the magnets; some parts of the cloth, usually in the vicinity of the poles, being bleached, and the colour so removed deposited in lines around the bleached portion.

This action, I found, was not a purely magnetic one, because on placing a piece of gutta-percha tissue over the wet blue cloth, and a magnet on the top of the gutta-percha, so as to prevent it from coming in actual contact with the wet cloth, no effect of any kind was produced after many weeks.

I next tried the effect of laying a horse-shoe magnet on a piece of wet cotton cloth dyed with aniline, and found that most of the colour was swept away in a semicircle in front of the poles, and it appeared as if the colour had been swept away from the south pole and deposited around the arc of the circle running from the north pole. Thus it is clear that a force of the nature of magnetism is capable of acting on aniline colour under certain conditions.

To find the action of a current of electricity on the prussian-blue colour, I placed some of the wet cloth on wet blotting-paper, and laid upon the cloth two platinum electrodes connected with a Leclanché battery; the current was allowed to pass during several days, and the result was that the colour under both electrodes was slightly bleached, but more so under the one than the other; whilst one, and only one, line of colour along the outside of one of the electrodes, was transferred to and penetrated six sheets of blotting-paper underneath.

Lastly, a strip of copper was laid on the prussian-blue cloth, and a weak current of electricity passed through it, to find what action the forces akin to magnetic, which surround the current, would have on the colour. The copper seemed to decompose the prussian-blue underneath it, producing prussiate of copper, which was transferred to the blotting-paper; but the most remarkable result was that some of the undecomposed blue colour was transferred to the blotting-paper in a broad, faint band (along one side only), about half-an-inch from the copper band.

---

6. *On the Specific Refraction and Dispersion of Light by Liquids.* *By* J. H. Gladstone, *Ph.D., F.R.S.*

The general conclusions arrived at from observations made on a large number of liquids were as follows:—

1. The original statement of the Rev. T. P. Dale and the author, that the length of the spectrum (the difference between the refraction of the lines A and H) decreases with elevation of temperature, is fully confirmed.

2. The original statement that this length of spectrum divided by the density $\left(\frac{\mu_H - \mu_A}{d}\right)$ is nearly, but not exactly, a constant at different temperatures, seems to be confirmed by more careful experiments.

3. It seems to be the general rule that this specific dispersion slightly diminishes with increase of temperature.

4. This specific dispersion is very notably affected by the constitution of the compound body. Thus among hydrocarbons, the change of the refraction-equivalent of the carbon from 5·0 to 6·1 or 8·8, reveals itself by a change in the specific dispersion far greater proportionally than that in the specific refraction.

5. While the specific refraction of a compound is the mean of the specific refractions of its constituents, no such simple law holds good with respect to specific dispersion.

7. *On Molecular Attraction.*[1] *By* F. D. Brown, *B.Sc.*

It is generally asserted by chemists that, when two or more elements combine together to form a compound body, the forces of chemical affinity brought into play are entirely neutralised by the act of combination. In this important respect, therefore, affinity is assumed to differ from gravitation where no neutralisation or diminution of the attractive force results from the contiguity of two masses of matter. The mere fact that chemical reactions take place, involving as they do the interaction of atoms forming part of dissimilar molecules, shows that this assumption of complete neutralisation is inconsistent with fact.

If we go to the other extreme, and say that the act of combination produces no change whatever in the chemical forces, but that the same attraction is excited between any given pair of atoms, without regard to the state of combination of one or both of the atoms, we are not only able to give a reasonable account of the occurrence of chemical reactions, and to assert that there is nothing very remarkable in the existence of molecular combinations, but we are also provided with a more or less effective explanation of the relative volatility of substances.

Let (rs) equal the attraction at unit distance exerted between any two atoms R and S; it is clear that the attraction between two contiguous molecules, each containing carbon, oxygen, and hydrogen, will be expressed as follows:—

$$A(co) + B(ch) + C(cc) + D(oh) + E(hh) + F(oo),$$

whence A, B, C, &c. are functions of the number and position of the corresponding atoms. Applying this general equation, as best we can, to actual cases, and especially to those cases which admit of a tolerably general statement, we find that the inter-molecular attraction should be greater in an acid than in the corresponding alcohol, greater in an alcohol of high molecular weight than in a homologous one of which the molecule is less complex, greater in a primary alcohol than in its secondary or tertiary isomer, generally greater in a chlorinated compound than in the corresponding substance containing hydrogen, and so on. If we allow that the volatility of a substance is in some sense a measure of the forces of attraction between the molecules, we must admit that the boiling points of the compounds of organic chemistry would lead us to infer with much reason that the above expression rightly represents the value of the inter-molecular attraction. The study of the latent heat of vaporisation of many of the carbon compounds would seem, from this point of view, to offer considerable chances of advancing the solution of the problem of chemical affinity.

---

8. *Note on a new method of Measuring certain Chemical Affinities.* *By* Alfred Tribe, *F.C.S.*

When a metal is immersed in an electrolytic field—*i.e.* in an electrolyte in the act of electrolysis—and the electromotive force set up on any part of its surface suffices to overcome the affinities of the radicals of the medium, the positive ion separates on that part of the surface which may be supposed to have received $-$ electrification, and the negative ion on that part which receives $+$ electrification.

When the metal is in the form of a rectangular plate, and placed so that the lines of force are perpendicular to its surface, the maximum electro-motive force set up is on the central parts of such a plate, becoming less towards the edges, where, and for some little distance from which, it is insufficient to initiate electro-chemical action.

When the plate is placed in the electrolytic field so that the lines of force are parallel with one of its edges, the maximum electro-motive force is on the end of the plate, becoming less and less towards the central parts until it no longer suffices to bring about electro-chemical action. This is denoted by the boundaries of the deposits, which in many cases are very sharply defined. A plate, in fact, in the position just named, may be regarded, in so far as electrical power is concerned, as a series of pairs of electrodes, the limits of the electro-deposits representing a pair,

[1] *Phil. Mag.* (5th series), 1881, vol. xii. p. 253.

the electro-motive force of which is just incapable of resolving the electrolyte into its constituent ions.

The very intimate relation between E.M.F. and Chemical Affinity was a long time ago pointed out by Sir W. Thomson, and recently in an elaborate research by Dr. Wright, and it therefore was anticipated that if, in a series of trials, the chemical affinities were altered, while other circumstances remained the same, the magnitude of the intermedial space between the boundaries of the electro-deposits would increase along with the force required to overcome the affinities of the ions of the electrolyte.

A series of experiments with molecular solutions of the chloride, bromide, and iodide of zinc, with rectangular plates or *analysers* of silver, copper, iron, and zinc, showed that this is the case—*i.e.* the intermedial space with the chloride was greatest, the bromide less, and the iodide least. Another series, with silver analysers, but with molecular solutions of the sulphates of zinc and copper, showed that the intermedial space in the case of the zinc sulphate was much the greater. Again, another series with zinc sulphate, showed that a zinc analyser gave the least intermedial space, iron greater, copper greater still, and silver most of all.

This method affords a simple means of demonstrating differences of chemical affinity, but whether it is capable of giving more than approximative measurements will require further investigation to determine. In some cases secondary actions are of course set up, so that the intermedial space would represent the initial electro-motive force + or − any interfering E.M. forces. Could, however, the difference of potential be determined between the boundaries of the electro-deposits, data would be furnished for calculating the chemical attractions overcome, or at least the work-equivalent of the net chemical actions involved.

TUESDAY, SEPTEMBER 6.

The following Papers were read:—

1. *On the present state of Chemical Nomenclature.* *By* Professor A. W. Williamson, *Ph.D., F.R.S.*

The object of this communication was to draw the attention of chemists to some of the discrepancies which have of late years sprung up in the principles upon which the names of chemical compounds are framed; to consider in what respects one of the principles adopted excels the other; and the importance of doing anything which may be possible to remedy the confusion which is being introduced into the science by the manufacture of heterogeneous terms.

---

2. *On Alterations in the Properties of the Nitric Ferment by Cultivation.* *By* R. Warington, *F.C.S.*

The earlier researches on nitrification conducted in the Rothamsted Laboratory have been already communicated to the Chemical Society. In the second communication ('Trans. Chem. Soc.,' 1879) some experiments were described (6th series, p. 451) in which a solution of chloride of ammonium, containing the usual nutritive ingredients, was seeded from an old solution which had some months before undergone a nitric fermentation; the result of this seeding was a purely nitrous fermentation, no nitric acid apparently being produced. Experiments have since been made on the conditions which respectively determine the formation of nitric and nitrous acid; a preliminary notice of the results is now communicated.

When a small quantity of fresh soil is employed to seed solutions of chloride of ammonium supplied with nutritive ingredients, a pure, or nearly pure, nitric fermentation is obtained if the solution is sufficiently shallow and dilute, and the temperature low; this is the case, for instance, when 80 milligrams of chloride of ammonium are present in one litre, the column of the liquid four or five inches in depth, and the temperature about 15° C. Under such circumstances only a trace of nitrous acid is formed, and this changes into nitric acid before the conclusion of the action. If the solutions employed are much more concentrated, or the temperature is considerably raised, large quantities of nitrous acid are produced; this formation of nitrous acid may be avoided to a great extent by diminishing the depth of the solution, but at the temperature of 30° it is very difficult to avoid the formation of considerable quantities of nitrous acid, even with small depths of solution. In all cases in which soil has been used as seed, the nitrous acid formed exists only temporarily in the solution, the final product of the fermentation being always nitric acid.

Soil added to a solution of nitrite of potassium, supplied with nutritive ingredients, readily converts the nitrite into nitrate.

When solutions, which have been seeded with soil and undergone the nitric fermentation, are themselves employed as seed for new solutions of ammonia, the final result as before is nitric acid; but this is apparently true only when the solution used as seed is not at most more than a few months old: beyond this age the result of the fermentation is apparently only nitrous acid, and this nitrous acid does not further change into nitric, even in several years, unless a certain visible change occurs in the solution to be presently mentioned. When a solution which has undergone this nitrous fermentation is used as seed, it again produces a purely nitrous fermentation, the nitrous acid being constant as before. The nitrous ferment just described is without effect on nitrite of potassium.

The results just mentioned are perfectly in accordance with the facts recently published by Pasteur, who finds that by allowing the cultivation of an organism (as that producing chicken cholera) to become old, an organism is obtained of diminished energy, which when cultivated continues to produce organisms of the same diminished energy.

If solutions which have nitrified are kept for a considerable time, a white organism not unfrequently appears in spots on the surface of the liquid, and under favourable conditions spreads over the whole surface. Viewed by a lens it appears as a mass of interlaced fibres. This organism has been examined microscopically by Dr. M. Masters, F.R.S., and more fully by Professor E. Ray Lankester; both pronounce it to be a bacterium. Wherever this surface organism appears, any nitrites that may be present are speedily converted into nitrates; a solution of nitrite of potassium is also speedily converted into nitrate. The experiments as yet made with this organism leave it doubtful whether it has any power of oxidising ammonia; this part of the subject requires, however, further investigation. There can be little doubt that this surface organism is a stage in the development of the nitrifying ferment.

The nitrifying ferment appears capable of existing in two, or perhaps three, conditions, producing definite chemical effects:—

1. The nitric ferment of soil, which converts both ammonium salts and nitrites into nitrates.
2. The altered ferment, which converts ammonium salts into nitrites, but fails to change nitrites into nitrates.
3. The surface organism, which changes nitrites into nitrates.

---

3. *On the Effect of the Spectrum of Silver Chloride.* *By* Captain ABNEY, *R.E., F.R.S.*

In all works with which the author is acquainted, the maximum intensity of the spectrum impressed on silver chloride is shown as situated in the indigo portion of the spectrum. Owing to a recent investigation by Dr. Eder, of Vienna, the possibility of developing an image on silver chloride by the alkaline developer, and by a ferrous citrate developer, has become practicable. The old method of developing by means of acid solutions was unsatisfactory and tended to give false impressions. The author experimented with chloride of silver prepared as an emulsion in gelatine.

Plates were prepared with this emulsion: in one case the silver chloride was modified in molecular structure by boiling the gelatinous solution, and in the other it was prepared by the cold method. Such plates were exposed to the spectrum and developed with a solution of hydrochloric and ammonium carbonate, and in other cases the development was with ferrous citrate.

The unmodified silver chloride, when examined by transmitted light, had a very faint canary colour; the absorption-spectrum of this was photographed, and showed that all the ultra-violet rays as far as H were not off, and that there was a slight weakening of the violet and indigo rays. On the principle of work going hand in hand with absorption, it was surmised that the rays most entirely absorbed should give the maximum effect when silver chloride was used as a receiving medium for the spectrum. This was proved to be the case, the limit of maximum effect being about H, the sensitiveness rapidly falling to 'h,' and being still less at G. Dr. Eder had examined the spectrum also, and found the maximum intensity in the violet. This discrepancy may be accounted for by the fact that the author's experiments were carried out in July, when the solar spectrum is very rich in ultra-violet rays; whilst Dr. Eder's were carried out with sunlight in the winter, when those rays were almost absent, or the spectroscope itself may be in fault.

Experiments with the electric light gave the same results with the author as those obtained with sunlight.

There is a practical bearing of these experiments in photographic printing on albumenised paper. In the process both albuminate and chloride of silver are the media acted upon by light; the spectrum on albuminate of silver has its maximum in the blue near G. If, then, we have light which possesses strongly the ultra-violet rays as well as the blue rays, we arrive at the fact that both the chloride and the albuminate will be strongly acted upon. If, on the other hand, we have a winter light, which is deficient in ultra-violet rays, we shall have the albuminate of silver much more acted upon than the chloride. Any practical worker in photography will have noticed that the appearance of silver prints of equal depth at the two seasons have very different qualities in toning, and this no doubt arises from the fact that the proportions of darkened chloride to albuminate vary very considerably in the two cases; the print resulting from light possessing much of the ultra-violet, being more vigorous than that produced, say, in winter. The author has in other papers shown that in slow printing a certain amount of oxidation of the altered chloride of silver is an accompaniment, and that this produces flatness of image when it is toned with gold; a still further cause for the same defect, the author believes, may be found in what he has already stated.

The author has 'printed out' the spectrum on chloride of silver, and finds that the same position of maximum as that it possesses when the image is developed holds good.

The author then proceeds to point out that, in actenometers based on the use of silver chloride, the rays measured chiefly lie in the ultra-violet region; and he proposes to try the substitution of bromized paper for the same purpose, and to compare them with the results obtained by the chloride paper.

4. *Some Remarks on Crystallogeny.* *By* Professor J. P. Cooke.

5. *On the Action of Zinc and Magnesium on Acidified Solutions of Ferric Sulphate.* *By* Professor T. E. Thorpe, *Ph.D.*, *F.R.S.*

The extent of reduction of the ferric salt may vary with the strength of the solution, with its temperature, with the amount of free acid present, and lastly with the specific nature of the metal employed. The author has studied the conditions under which the hydrogen does work as a reducing agent. Experiments were made on dilute solutions of ferric sulphate, containing known quantities of free acid. The author finds: (1) that the amount of reduction produced by a given weight of zinc in dissolving increases with the temperature; (2) that it is also affected, although to a less degree, by the initial surface of metal exposed. Whilst the extent of reduction, as also the rapidity of solution, increase with the temperature, at a given temperature the extent of reduction increases, although at a gradually diminishing rate, with the time of solution. The rapidity of solution and extent of reduction, produced by a given quantity of zinc of a given area and in a solution of a given temperature and containing a definite weight of free acid, increases with the amount of reducible iron present. Experiments made by placing zinc in contact with platinum showed that, although the time of solution of zinc in contact with platinum, is considerably diminished, as compared with that of zinc alone, little difference in the reducing effect is observed.

Similar results were obtained with magnesium, although the amount of reduction is from one-fourth to one-third of that produced by zinc, under similar conditions. The diminution of the rate of solution with decrease in the amount of free acid present, is far greater in the case of magnesium than in that of zinc.

The author concludes that his experiments strongly support the view that the reducing power of nascent hydrogen is connected with the existence of this body in the atomic condition, since all conditions tending to prolong the duration of this atomic condition augment the reducing power.

---

6. *On the Reducing Action of Zinc and Magnesium on Vanadium Solutions. By* Professor H. E. Roscoe, *LL.D., F.R.S.*

The object of this communication is to examine the reducing action of the above metals upon acid Vanadic Solutions, comparing the relative amount of reduction effected by metals generally, together with the time occupied by that reduction, other conditions remaining as nearly constant as possible. From his original experiments on this subject the author concluded that, whilst the reduction in the case of zinc and sodium took place from V_2O_5 to V_2O_2, that in the case of magnesium only proceeded to V_2O_3. This he now finds is so far not the case that the same point is in reality reached by all three above-named metals, but that the reduction from V_2O_3 to V_2O_2 takes place with magnesium with extreme slowness. Curves of the reduction in terms of the time are given.

---

7. *On the Determination of the Relative Atomic Weights of Manganese, Oxygen, and Silver. By* Professor Dewar, *M.A., F.R.S., and* A. Scott, *B.A., B.Sc.*

Considerable doubt seems to exist as to whether the atomic weight of manganese should be taken as 54 or 55. It seemed to the authors that by the use of permanganate of silver this could be determined with great accuracy, as it is only needful to assume the atomic weights of oxygen and silver, which are the two elements, the atomic weights of which have been most accurately determined by Stas. It is an exceedingly good substance for this purpose, as it can readily be obtained in a state of high purity, and can be readily weighed, as it is an anhydrous salt and is not hygroscopic in the slightest degree. It contains likewise manganese free from any allied metals, and may be decomposed without the intervention of any solution. By heating it to a temperature of about 100° to 105° it decomposes thus:—

$$4AgMnO_4 = 2(Ag_2O.2MnO_2) + 3O_2$$

If this residue, which seems to be a comparatively stable and definite compound, be heated in hydrogen we have this decomposition:—

$$Ag_2O2MnO_2 + 3H_2 = Ag_2 + 2MnO + 3H_2O.$$

From these decompositions they expect very accurate results. As a further check they dissolve the oxide of manganese out of this residue by means of dilute sulphuric acid containing a little sulphurous acid, wash thoroughly and thus leave the silver behind. The decompositions are done in a bulb of hard glass. Three experiments, made on different samples of the salt, give the following values for manganese, silver being taken as 108 and oxygen as 16.

55·51
54·04
54·45

The two latter samples were the finest. It is evident that there is some impurity contained in these samples, which were quite free from potash when a quantity of 5 grams was reduced, extracted with water, and tested spectroscopically.

To check these results two samples of black oxide of manganese, obtained by heating the nitrate, were reduced in hydrogen to manganous oxide, and the water collected. These gave for manganese the atomic weights of 53·6 and 53·3 respectively. These are the results of preliminary experiments; others are being carried out with purer samples and greater accuracy.

WEDNESDAY, SEPTEMBER 7.

The following Papers were read:—

1. *On Some Vapour Density Determinations. By* Professor DEWAR, *M.A., F.R.S., and* A. SCOTT, *B.A., B.Sc.*

It seemed to the authors that the behaviour of various haloid salts at high temperatures would prove of great interest on account of its relation to the experiments of Meyer and Crafts on the vapour density of chlorine at high temperatures. The method they employed was to measure the volume of gas given off from a weighed amount of substance which was introduced in the ordinary way into an iron apparatus in every respect the same as they used in determining the vapour-densities of potassium and sodium, which is described in the 'Proc. Roy. Soc.' The results of the experiments are calculated so as to give the amount of substance required to expel 22·4 C. of gas at 0° + 760 mm. pressure. Commencing with iodine they found that in an apparatus filled with hydrogen the mean result was 260, I_2 being equal to 254; when nitrogen was used, 241 was the number found.

Platinous chloride gave in the same way the number 251, 268 corresponding to Cl_2. No free chlorine could be detected; ferrous chloride was apparently formed alone. Ferrous chloride was next tried and gave as a mean 116:—

$$FeCl_2 = 127.$$

No absorption-spectrum could be seen, but a small quantity of free chlorine seemed to exist in the vapour, the rest being $FeCl_2$. Manganous chloride gave 135 while $MnCl_2 = 126$. Argentic chloride when introduced seemed to volatilise at once, and on calculating gave 262 as a mean instead of 287. It, however, was almost entirely decomposed into ferrous chloride and silver, as on blowing out the vapour only a minute trace of silver could be found.

With argentic iodide they got the number 428 if the iodide was first fused in the small capsule before being introduced into the apparatus; otherwise they got the number 574, Ag_2I_2 corresponding to 470. In the vapour there were silver and ferrous iodides along with free iodine; lead chloride gave 239, whereas $PbCl_2$ corresponds to 278. On looking down the tube with the spectroscope a beautiful channelled spectrum was observed. Potassium chloride was tried, but they were never able to raise the temperature sufficiently to volatilise this salt rapidly enough to get good results. Potassic iodide gave as a mean 183 instead of 166. The vapours blown out seemed to contain neither iodine nor iron, but yielded a fine white powder of potassic iodide which had a slight acid reaction. Rubidium chloride similarly gave 155 instead of 121.

---

2. *On Vapour Density Determinations. By* Professor THORPE, *Ph.D., F.R.S.*

---

3. *Note on the Phosphates of Lime and Ammonia. By* J. ALFRED WANKLYN.

When ammonia is added to a solution of the soluble phosphate of lime, a precipitate of tribasic phosphate of lime is thrown down, and phosphate of ammonia passes into solution.

The author has observed that *re-solution* of the phosphate of lime occurs when the ammoniacal solution is heated with it in the water-bath, and that a clear viscid solution is formed which, on cooling, solidifies and yields a solid, admitting of being reduced to a fine powder. This double salt (which he believes is new) appears to have the following formula:—

$$P_2O_5CaO(NH_4)_2O,H_2O + aq.$$

Excess of water breaks it up. Morfit has made the interesting observation that when tribasic phosphate of lime (bone-earth) is dissolved in acid and then reprecipitated with an alkali, it is reprecipitated in the form of hydrated tribasic phosphate of lime. He has recently had an opportunity of confirming this observation on a very large scale, and the resulting hydrated tribasic phosphate is likely to become of great importance in agriculture.

---

4. *On a New System of Blowpipe Analysis.*[1] *By* Lieut.-Colonel Ross.

Among others, the following are points of novelty:—

1. The use of aluminium plate for volatilising substances.
2. A new air-reservoir mouth blowpipe.
3. A blowpipe or pyrological candle.
4. Candle-scissors; also used for general purposes.
5. The use of watchmakers' pliers for holding, cleaning, and ringing platinum wires.
6. Agate slabs instead of the ordinary mortar for grinding powders.

Reagents.

7. Boric acid (instead of borax).
8. Phosphoric acid instead of microcosmic salt.

Miscellaneous Novelties.

9. An alloy button of gold and silver, in which these metals have been separated by the blowpipe alone.
10. A spectrum lorgnette, or spectracles, for observing blowpipe spectra while you are producing them.
11. A compass, in which the needle points E. and W., for obviating the 'dip' in Arctic voyages.

---

5. *On Colliery Explosions. By* William Galloway.

The author first described the general arrangement of the airways and workings in a large modern colliery, worked according to the long-wall method, and passed on to notice some hypotheses which had been entertained by himself and others on the causes of firedamp explosions. As regards that attributing an influence to atmospheric pressure, it had been found by Mr. R. H. Scott and himself, that while shallow mines are affected by changes of weather, large and deep mines, in which great explosions nearly always occur, are not perceptibly affected by them.

It had occurred to him that possibly a mixture of firedamp and air, which contains too small a proportion of firedamp to render it explosive at ordinary pressure and temperature, might become so when traversed by a wave of compression originated by a local firedamp explosion or by a blown-out shot.

About the same time it occurred to him also, that the sound-wave originated by a blown-out shot might carry the flame through the meshes of a safety-lamp burning in an explosive mixture. Experiments had justified this hypothesis (see 'Proc. Royal Soc.,' 1874).

None of the foregoing hypotheses could account for all the phenomena observable after a great explosion; and, in pursuing the subject still further, he began, towards the end of the year 1874, to speculate as to the probable influence of the coal-dust which is to be found nearly everywhere on the floor of dry and dusty mines. Further investigations led him to the conclusion that if a mixture of coal-

[1] Detailed Paper published in the *English Mechanic and World of Science*, of September 30, 1881.

dust and pure air were not inflammable at ordinary pressure and temperature, it would become so when a small proportion of firedamp was added; and that the coal-dust might thus become the vehicle for conveying flame from one district of a mine to another, after it had been raised from the floor and mixed with the air of the mine by some disturbing cause, such as a local explosion of firedamp or a heavily charged blown-out shot. This view, that coal-dust and not firedamp plays by far the most prominent part in great explosions, has been confirmed by all his subsequent observations, of which the following is a sketch:—

1. In July 1875 he found that an air-current made black with fine coal-dust was not ignited by the flame of a lamp, but that when the air contained a small proportion of firedamp (insufficient to render it inflammable alone) it became inflammable when the same proportion of coal-dust was added to it and burned with a red smoky flame that filled the apparatus.

2. In December 1875 he made a quantitative experiment with the view of ascertaining the proportion of firedamp required to produce the foregoing results, and he found that one per cent., or rather less, was sufficient to do so. He attributes the satisfactory character of this result, and of all the results of his later experiments with coal-dust, to the fact that he has employed only wind-carried dust in making them, and this dust has not parted with its finest particles like that which is to be found under screens and in other exposed situations.

3. In June, 1876, Messrs. Hall and Clark read a paper before the North of England Institute of Mining Engineers, describing experiments which showed that the flame of a blown-out shot was prolonged to a distance of fifty yards, when it was directed in such a manner as to lick up coal-dust strewed on the floor of a sloping gallery. During the same year the author had practical proof of the same thing in a Welsh mine, in which two explosions of coal-dust, by which men were burnt and injured, were originated in this way, but the explosions died out again when they reached damp portions of the roadways.

4. Professor Freire-Marecco, of the College of Physical Science, Newcastle-on-Tyne, commenced a series of experiments in 1876, and has continued them on a larger scale since then, and he has obtained results similar to the foregoing by means of a special apparatus.

5. In 1878 he made three sets of experiments with different kinds of apparatus:—

a. In the first set, in which lighting gas was used instead of firedamp, and the gas and air were carefully measured and the coal-dust weighed, it was shown that $2\frac{1}{2}$ per cent. of gas mixed with air was rendered inflammable when coal-dust was added; 3 per cent. of gas made the mixture slightly explosive; 4 per cent. made it still more explosive; and 5 per cent. produced a violent explosion. The total quantity of gas and air mixture was little more than a cubic foot.

b. In the second set it was shown that the return air of a mine containing 2 per cent. of firedamp became inflammable when coal-dust was added to it.

c. In the third set the explosion of a mixture of air and firedamp was made to raise and ignite coal-dust scattered along the floor of an artificial gallery, 70 or 80 feet long, and 14 inches square inside. The flame of the firedamp explosion alone was found to be 7 or 8 feet long; the flame of coal-dust in pure air was 35 or 40 feet long; and the flame of coal-dust in the return air employed in experiment *a* was 80 or 90 feet long. The two sets of experiments *b* and *c* were described in the 'Proceedings of the Royal Society,' March 1879, and the set *a* has been described in a general way more recently.

6. The great explosions of Risca, Seaham, and Penygraig Collieries took place in the year 1880, and all of them appeared to be wrapped in the usual mystery when viewed only from the firedamp standpoint. It was under these circumstances that the Home Secretary requested Professor Abel to inquire into the causes of the Seaham explosion, and to ascertain if possible what influence, if any, the coal-dust was likely to have had in promoting the explosion. Professor Abel made experiments near Wigan, with an apparatus similar to the one the author had employed in July 1875, and obtained results similar in kind, but different in some respects. He found that $2\frac{1}{2}$ to $3\frac{1}{2}$ per cent. of firedamp was required to render a

mixture of air and coal-dust inflammable; and that dust containing no combustible matter produced flashes of flame in the apparatus when the air contained 3 to $3\frac{1}{2}$ per cent. of firedamp. The author attributes the high percentage of firedamp required in the first case to the coarseness of the dust employed, since he obtained similar results on using coarse dust instead of very fine. The second result appears to be a curious one, but some light will doubtless be thrown upon it by future experiments.

7. In July of the present summer the author made experiments, during the six days of very warm dry weather ending on the 21st of that month, with an apparatus of the following description. A sheet-iron cylinder, 6 feet long by 2 feet in diameter, closed at one end and open at the other, has its open end bolted to a wooden gallery, 126 feet long by 2 feet square inside. One end of the wooden gallery is thus closed by the sheet-iron cylinder or explosion-chamber, and the other end is open. Six sheets of newspaper are placed between the open end of the explosion chamber and the gallery, and a tight joint is insured by means of the screws. Rather less than two cubic feet of firedamp is carefully measured by means of water displacement, and introduced into the explosion-chamber. The wooden gallery contains only pure air. The firedamp contained in the explosion-chamber could not find its way into the gallery except by passing *through* the six sheets of newspaper, and if any part of it did so, it would be immediately carried away by a strong current of pure air, amounting to 1,000 or 1,200 cubic feet per minute, which enters the gallery just behind the paper, and traverses its whole length towards the open end. It is thus doubly certain that the gallery contains nothing but pure air. The air and firedamp contained in the explosion-chamber are thoroughly mixed by means of an appropriate mechanical arrangement, and the mixture is exploded. The explosion bursts the sheets of paper, and the resulting flame travels about 12 or 14 feet along the gallery, and as suddenly disappears. The gallery is then strewed with a layer of fine coal-dust, from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch thick, along its floor, and some is placed on shelves which stand in sets of three, one above the other, at distances of 10 feet from each other, along the gallery. The same arrangement as before is then made in regard to preparing for a firedamp explosion, exactly the same quality of firedamp being measured, mixed, and exploded.

By the explosion of the firedamp mixture the coal-dust is raised in a cloud throughout the whole length of the gallery, part of it is projected out into the air to a distance of 20 or 30 feet beyond the end, and, after the lapse of an appreciable interval of time, the flame finds its way to the end of the gallery, and flashes out through the cloud of dust to a greater or less distance, according to circumstances. The greatest lengths of flame thus obtained with coal-dust and pure air was 147 feet on one occasion, and from 100 to 140 feet very often.

The author considers that these results prove in the most convincing manner that coal-dnst forms an inflammable mixture with pure air, and they settle once for all the question as to how an explosion, begun in one district of a dry and dusty mine, can penetrate to the most distant parts of every other district of workings in the same mine.

If, then, water were sprinkled on the floor of all dry mines from time to time, and always before firing blasting shots, we should, in the author's opinion, have no more disastrous colliery explosions, such as those with which we have become but too familiar during the last ten or fifteen years.

---

6. *On the Double Iodide of Mercury and Copper.* *By* Professor SILVANUS P. THOMPSON, *B.A.*, *D.Sc.*

Cuprous mercuric iodide, Cu_2HgI_4, is prepared by the following process. Mercuric biniodide is dissolved in iodide of potassium; the liquid is then raised to 100°, and aqueous solution of cupric sulphate is added in excess, when the cuprous mercuric iodide precipitates. When cold, it is of a fine scarlet colour; but possesses the property of becoming a deep dull black tint, between 80° and 90°, without suffering decomposition, and of returning on cooling to its former hue. This remarkable phenomenon, possessed by many bodies in less degree, led the author to select it from amongst bodies whose colour changes with heat, to verify one point of the electro-magnetic theory of light. According to that theory, all good conductors of electricity should be opaque to light; and therefore, if this theory holds good, the increase of opacity and of light-absorbing power by a body should indicate that its electrical conductivity was increasing. To put this to the test the author has measured the conducting power of the iodide at various temperatures. This was done by placing a film of the iodide about 1 millimetre thick between two plates of platinised lead, each 10 centimètres square, and determining its resistance in a Wheatstone's bridge at different temperatures. A decrease was observed from 40° C. up to about 110° C., at which the resistance began again to increase. The author believes this increase to be due to dissociation setting in, as at about 150° C. it is decomposed, mercuric iodide subliming away and leaving pale brown cuprous iodide behind. The greatest change of resistance was between 65° C. and 90° C. with rising temperatures, and between 95° C. and 75° C. with falling temperatures. In both cases the maximum rate of increase of conductivity was between 87·5° and 88·5° C., precisely the temperature at which the rate of change of tint is also a maximum. The specific electric conductivity doubles between 82° and 92°. The following values of χ, the specific electric conductivity, were obtained:—

$$\begin{array}{lll} \text{At } 50^\circ \text{C. } \chi & = & 2{\cdot}396 \times 10^{-8} \\ \quad 82^\circ & = & 9{\cdot}865 \times 10^{-8} \\ \quad 92^\circ & = & 18{\cdot}64 \times 10^{-8} \\ \quad 109^\circ & = & 23{\cdot}95 \times 10^{-8} \end{array}$$

The maximum value of $\frac{d\chi}{d\theta}$ was $0{\cdot}221 \times 10^{-7}$.

These results were therefore held to support the theory, though experiments on other bodies exhibiting similar phenomena were to be desired in confirmation, before any sweeping generalisation would be admissible.

The author pointed out, in conclusion, that the remarkable change of colour exhibited by this body rendered it a valuable thermoscope for lecture purposes. He had employed it for demonstrating to an audience the heating effects of absorption of radiation, the conductivity of heat in crystals, and the heat produced by magnetic and mechanical friction.

---

7. *Analyses of the Water and Gas from Blowing Wells near Northallerton. By* T. Fairley, *F.R.S.E.*

The wells are three in number:—Well at Solberge, 3½ miles S. from Northallerton; well at Langton, about 4 miles W.N.W. from Northallerton; and well at Ornhams, 2 miles S. from Boroughbridge. In each of these currents of air flow from the shafts of the wells during a falling period of the barometer, and inward currents flow into the shafts while the barometer is rising. When the rise or fall is considerable the currents are very powerful, causing a strong draught or wind in the openings leading to the shaft.

The well at Solberge is situated on Mr. Hutton's estate near his residence. Through this gentleman's kindness and assistance the author was able to make a number of experiments. A number of analyses of the gas from the out-current showed it to be common air containing 20·9 per cent. of oxygen. Analyses of the water gave the results (grains per gallon):—

Chloride of sodium	4·1	
Calcium sulphate	6·36	Hardness before boiling, 32·6°
„ carbonate	16·24	
Magnesium carbonate . . .	11·36	
Alumina and oxide of iron . .	0·03	
Silica	0·21	„ after boiling, 8·4°
Organic matter, loss . . .	0·34	
Total solids by evaporation .	38·64	

As the author conceived, there must be a large cavity communicating with the shaft of the well, at his request Mr. Hutton had the well opened, and on descending with a candle he easily found the fissures in the sandstone, through which the air was passing at a depth of about 15 yards from the surface.

A piece of this sandstone, broken off at the side of the fissure, contained the following:—

Moisture	1·25	
Silica	87·72	
Ferric oxide, with traces of alumina	3·96	
Lime	3·58	Carbonates of calcium and magnesium, 7·05
Magnesia	0·32	
Carbonic acid	3·15	
Sulphuric acid	a trace	
Loss	0·02	
	100·00	

To obtain the approximate volume of the cavity by the application of Boyle's law, careful readings were taken of the barometer at Solberge, and the current was measured, first by means of an anemometer, afterwards by means of very large dry gas-meters. The results of numerous observations made by Mr. Hutton, selecting those where the current due to the change of pressure had had sufficient time to expend itself, give an approximate volume of about ten million cubic feet, corresponding to a cubic space measuring 217 feet each way.

The currents at the other wells also consist of air, and vary with the barometric pressure.

---

8. *On Experiments with Manures on the Barley Crop of* 1881. *By* W. Ivison Macadam.

The author said that he was engaged in a large series of experiments with the various crops, to determine the best seasons for the application of different manures and the results of the various treatments. A large number of results had been obtained, but the present Paper was restricted to the consideration of two lots of barley, the first of which was grown on land from which a previous turnip crop had been eaten by sheep, and in the case of the second the turnips had been carted off the land. The results showed that the water, which was most large during the earliest stages of growth, gradually decreased with an increasing amount of organic vegetable matter during the ripening process. The results also showed that the effect of eating the turnips on the land was best seen on the commencement of wet weather, when the barley on the land so treated rushed forward and became much more healthy in appearance and heavier in weight than the second sample, and that it also yielded a heavier crop on ripening.

---

9. *On the Hydration of Salts and Oxides.* *By* C. F. Cross, *B.Sc.*

The author bases his method of observation of the rate of hydration of salts and oxides, viz., confinement over water of the substances in bell-jars of 2,000 cc. capacity, and in quantities of 1·25 grms. or less, and distributed in the finest state of division over a circular area of 60 mm. diameter, upon a critical experimental investigation. As a typical instance of the results obtained, details are given of the observations of the hydration of *Copper Sulphate* ($CuSO_4.H_2O$). Combination with water proceeds with diminishing velocity up to the point corresponding to the pentahydrate, at which it remains constant for some hours, after which *deliquescence* sets in, and the combination with water continues until a liquid mass is obtained. *Potassium Dichromate* represents another class of salts which appear to condense water into their substance, rather than combine with it (although the quantity taken up is observed to be in simple molecular ratio), since they are again rendered anhydrous by pressure between blotting paper, or short exposure to ordinary air. *Potassium Sodium* and *Magnesium Sulphates* pass continuously through hydration to deliquescence.

Ferric Oxide (ppt. dry at 100°) rapidly combines with 1 mol. H_2O, after which it slowly takes up a further 3 mols.; on exposure to the air it loses 2 mols., and in the form of the trihydrate appears to be stable. The hydration of the oxides and of all bodies is greatly influenced by methods of preparation.

---

10. *On Cellulose and Coal.* *By* C. F. Cross, *B.Sc.*, *and* E. J. Bevan.

The authors have obtained, by the action of sulphuric acid upon cellulose, black substances, resembling coal in appearance and percentage-composition (C O and H), which are convertible, by the action of chlorine, into derivatives, resembling those obtained by the direct chlorination of lignefied fibres. The yield of the black substance is about 35 per cent. of the original substance (dextrin), *i.e.* in view of its higher carbon percentage (60° to 70°) about 50 per cent. of the carbon of the carbohydrate takes this aromatic form, the remainder being liberated as carbonic and acetic acids, &c. The passage of cellulose into these compounds suggests the probability of its conversion into lignin as a result of plant-life. In support of this view the authors cite their experiments on the probable existence of plant-constituents intermediate between the two groups (jute); Meisseur's experiments on the origin of the hippuric acid of the urine of herbivora, which he refers to a constituent of hay containing a benzoic residue, and which appears to be a form of cellulose: the formation of astringent bodies at the expense of plant-structures, as in the 'pathological' tannins and the decay of the jute-fibre; the occurrence of tannin and carbohydrates in intimate association throughout the plant world; and, lastly, the chemistry of coal. They regard cellulose, lignin, peat, lignite, and anthracite as, probably, terms of a vast series of compounds differentiated under conditions which we can only very approximately imitate or even conceive.

---

11. *On the New Element, Actinium.* *By* Dr. T. L. Phipson, *F.C.S.*

The author has at last succeeded in isolating the new metallic element which he has found in white zinc pigment, to which it gives the peculiar property of darkening in about twenty minutes when exposed to the direct rays of the sun, but not so when protected by a sheet of glass, and becoming again white in the course of a few hours when placed in the dark.

The new metal has been obtained in the form of *oxide* and in the form of *sulphide*. Its isolation is based principally upon the facts, that its oxide is only slightly soluble in caustic soda, and not precipitated by ammonia from solutions containing salts of ammonia; that its sulphide is scarcely soluble in acetic acid, but readily soluble in mineral acids, even when they are slightly diluted. He has proved that it differs essentially from zinc, cadmium, manganese, and lanthanum, with which alone it is possible, for a moment, to confuse it. He has obtained no less than about four per cent. from some white zinc pigment as found in commerce. This yield is enormous. The presence of this new metal in commercial zinc will fully explain discrepancies as to the equivalent of that metal.

After a great number of experiments he has adhered to the following simple process for the extraction of actinium:—

1. The pigment (about 12 grammes) is digested for twenty-four hours in dilute acetic acid, washed and digested for another twenty-four hours in dilute hydrochloric acid (8 per cent.), and the residue washed.

2. The residue is dissolved in strong hydrochloric acid, with occasional additions of nitric acid; the chlorides are treated with excess of caustic soda, which leaves oxide of actinium and dissolves the oxide of zinc. The oxide of actinium is dissolved in hydrochloric acid, and again treated with excess of caustic soda (the operation is repeated two or three times); finally, to separate a little oxide of iron, the oxide of actinium is dissolved in excess of HCl, and the solution treated with excess of ammonia, which only precipitates the iron. The oxide of actinium remaining in solution is precipitated by sulphide of ammonium.

Oxide of Actinium.—The hydrate forms a bulky white precipitate, more gelatinous than oxide of zinc. Unlike the latter, it is only slightly soluble in caustic soda. It is not precipitated by ammonia in presence of ammoniacal salts. It is a permanent white, with a slight salmon-colour tinge; calcined, the tint is similar. It does not change colour by exposure to the air, neither does it appear to be affected by sunlight. It is readily soluble in acids.

Sulphide of Actinium.—The hydrate, as precipitated from its neutral or alkaline solutions by sulphide of ammonium, is a bulky, pale, canary-yellow precipitate; insoluble in excess of sulphide of ammonium, very slightly soluble in acetic acid, readily soluble in mineral acids, even when rather dilute. Exposed to the direct rays of the sun it darkens in about twenty minutes, except where protected by a piece of glass.

12. *On Bowkett's Thermograph.* *By* Wm. Lant Carpenter, *B.A., B.Sc., F.C.S.*

The construction of this instrument is based on an application of the principle of Bourdon's steam-gauge, the changing pressure of a confined fluid under varying temperatures being used to obtain a motion for registering those temperatures. Upon a flat, circular, metallic vessel, 3 inches in diameter and $\frac{3}{8}$-inch thick, is a hollow metallic spring or sealed tube communicating with it, filled with fluid, circular in shape, and fixed at one end. The other end is free to move, and very minute changes in temperature cause it to do so, the amount of movement being proportionate to the pressure, and this again proportional to the increase of temperature producing the expansion. The movements are magnified by a lever system, and recorded by a pen upon a cardboard disc, rotating once in twenty-four hours, divided by concentric circles into degrees, and into hours by radial lines. The instrument had been extensively used, clinically and otherwise, and would be useful in the laboratory for recording purposes, where a prolonged constant temperature was necessary.

Section C.—GEOLOGY.

President of the Section—Andrew Crombie Ramsay, LL.D., F.R.S., F.G.S.

THURSDAY, SEPTEMBER 1.

The President delivered the following Address:—

On the Origin and Progress of the present state of British Geology, especially since the first meeting of the British Association at York in 1831.

In the year 1788, Hutton published his first sketch of his 'Theory of the Earth,' afterwards extended and explained by Playfair in a manner more popular and perspicuous than is done in Hutton's own writings. In this grand work, Hutton clearly explains that the oldest known strata, like their successors, are derivative, and that as far as *observation* can discover, in all geological time, 'we find no vestige of a beginning, and no sign of an end." The complement to this far-seeing observation was at length brought about by William Smith, in his original 'Geological Map of the Strata of England and Wales' in 1815, followed, in 1816, by his 'Strata Identified by Organised Fossils.' This great discovery, for such it was, threw a new light on the history of the earth, proving what had before been unknown, that all the 'secondary' formations at least from the lias to the chalk inclusive, contained each a set of distinctive fossils by which it could be recognised. A law was thus provided for the identification of formations which geographically are often widely separated from each other, not only in England in the case of minor outliers, but also easily applicable to great areas on the neighbouring continent of Europe.

In 1811, the first volume of the 'Transactions' of the Geological Society was published, and in 1826-27, there appeared the first volume of the 'Proceedings,' the object being to communicate to the fellows as promptly as possible the proceedings of the Society 'during the intervals between the appearance of the several parts of the Transactions.' The last volume of the 'Transactions' contains memoirs read between the years 1845-1856, and only four volumes of the 'Proceedings' appeared between the years 1826 and 1845 inclusive, after which the title of the annual volume was changed to that of the 'Quarterly Journal of the Geological Society.' The Geological Society, to which the science owes so much, was therefore in full action when the British Association was founded in 1831, and the memoirs read before the society from 1831 to this date, may be said to show generally the state of British geology during the last fifty years. To this must be added the powerful influence of the first (1830) and later editions of Lyell's 'Principles of Geology,' a work which helped to lay the foundations of those researches in Physical Geology which in both earlier and later years have attracted so much attention.

Fifty years ago in this city, Viscount Milton was president of the first meeting of 'The British Association for the advancement of Science,' which he explained had for its chief object 'to give a stronger impulse and more systematic direction to scientific inquiry.' In his address, he pointed out the numbers of Philosophical Societies which had by degrees sprung up in all parts of the kingdom; and the practicability, through the means of the Association, 'including all the scientific strength of Great Britain,' 'to point out the lines in which the direction of science should move.'

In that year, 1831, Professor Sedgwick was president of the Geological Society, and the Geological and Geographical Committee of the British Association recommended that geologists should examine the truth of that part of the theory of Elie de Beaumont, in its application to England, Scotland, and Ireland, which asserts that *the lines of disturbance of the strata assignable to the same age are parallel*; that Professor Phillips be requested to draw up *a systematic catalogue of all the organised fossils of Great Britain and Ireland*; and that Mr. Robert Stevenson, civil engineer, be requested to prepare a report upon *the waste and extension of the land on the east coast of Britain, and the question of the permanence of the relative level of the sea and land.*

In 1881 it seems strange to us that, in 1831, with William Smith's map of 'The Strata of England and Wales, with part Scotland' before them, it should have been considered necessary to institute an inquiry as to the truth of the general parallelism of disturbed strata, which, in a limited area like England, had suffered upheaval at different successive epochs; and we may fancy the internal smile with which Phillips, the nephew of Smith, regarded the needless proposal. The masterpiece of the old land surveyor and civil engineer remains to this day the foundation of all subsequent geological maps of England and Wales; and *as an unaided effort of practical genius*—for such it was—it seems impossible that it should be surpassed, in spite of all the accuracy and detail which happily modern science has introduced into modern geological maps.

The first paper read at York, in the year 1831, was by Professor Sedgwick, 'On the general structure of the Lake Mountains of the North of England.' This was followed by 'Supplementary Observations on the Structure of the Austrian and Bavarian Alps,' by the Secretary of the Society, Mr. Murchison, a memoir at that time of the highest value, and still valuable, both in a stratigraphical point of view, and also for the light which it threw on the nature of the disturbances that originated the Alpine mountains, and their relations in point of date to the far more ancient mountains of Bohemia. In his elaborate address in the same year, on his retiring from the president's chair, he largely expatiates on the parallelism of many of the great lines of disturbance of what were then distinguished as the more ancient *schistose* and *greywacké* mountains, and quotes the authority of Elie de Beaumont for the statement, 'that mountain chains elevated at the same period of time, have a general parallelism in the bearing of their component strata.' On a great scale this undoubtedly holds true, as, for example, in the case of the Scandinavian chain, and the more ancient palæozoic rocks north of Scotland, Cumberland, and even of great part of Wales. The same holds good with regard to the parallelism of the much more recent mountain ranges of the Apennines, the Alps, the Caucasus, the Atlas, and the Himalayas, all of which strike more or less east and west, and are to a great extent of post-Eocene, and even partly of post-Miocene age. The same, however, is not precisely the case with the Apalachian chain and the Rocky Mountains of North America, the first of which trends N.N.W., and the latter N.N.E. The remarkable chain of the Ural Mountains trends nearly true north and south, and is parallel to no other chain that I know of, unless it be the Andes and the mountains of Japan. It is worthy of notice that the chain of the Ural is of pre-Permian age according to Murchison, while Darwin has shown that the chief upheaval of the Andes took place in post-Cretaceous times.

The Apalachian chain is chiefly of post-Carboniferous date, and the Rocky Mountains have been re-disturbed and re-elevated as late as post-Miocene times.

In the same address Professor Sedgwick entered an eloquent protest against the broad uniformitarian views so powerfully advocated in the first edition of Lyell's 'Principles of Geology' in 1830, in which, throwing aside all discussion concerning cosmogony, he took the world as he found it, and agreeing with Hutton that geology is in no ways concerned with, and not sufficiently advanced to deal 'with questions as to the origin of things,' he saw that a great body of new data were required such as engaged the attention of the Geological Society (founded in 1807), which along with other foreign societies and private work has at length brought geological science to its present high position.

And what is that position? With great and consentient labour many men gifted with a knowledge of stratigraphical and palæontological geology, have, so to speak, more or less dissected all the regions of Europe and great part of North America, India, and of our colonies, and in vast areas, sometimes nearly adjoining, and sometimes far distant from each other, the various formations, by help of the fossils they contain, have been correlated in time, often in spite of great differences in their lithological characters. It is easy, for example, to correlate the various formations in countries so near as Great Britain and Ireland, or of the Secondary and Lower Tertiary formations of England and France; and what is more remarkable, it is easy to correlate the palæozoic formations of Britain and the eastern half of the United States and Canada, even in many of the comparatively minute stratigraphical and lithological subdivisions of the Silurian, Devonian, and Carboniferous formations. The same may be said with regard to some of the palæozoic formations of India, China, Africa, and Australia, and many of the secondary and tertiary deposits have in like manner been identified as having their equivalents in Europe. It is not to be inferred from these coincidences that such deposits were all formed *precisely* at the same time, but taken in connection with their palæontological contents, viewed in the light which Darwin has shown with regard to the life of the globe when considered in its relation to masses of stratified formations, no modern geologist who gives his mind to such subjects would be likely to state, for example, that in any part of the globe Silurian rocks may be equivalents in time to any of our Upper Palæozoic, Mesozoic, or Tertiary formations.

For all the latest details of *genera* and *species* found in the British Palæozoic rocks, from those of St. David's, so well worked out by Dr. Hicks, to the Carboniferous series inclusive, I must refer to the elaborate address of Mr. Etheridge, President of the Geological Society, which he delivered at the last anniversary meeting of that Society. It is a work of enormous labour and skill, which could not have been produced by anyone who had not a thorough personal knowledge of all the formations of Britain and of their fossil contents.[1]

In connection with such subjects I will not in any way deal with the tempting and important subject of cosmological geology, which in my opinion must go back to times far anterior to the date of the deposition, as common sediments, of the very oldest known metamorphic strata. Cosmological speculations perhaps may be sound enough with regard to the refrigeration, and the first consolidation of the crust of the earth, but all the known tangible rocky formations in the world have no immediate relation to them, and in my opinion the oldest Laurentian rocks were deposited long after the beginning and end of lost and unknown epochs, during which stratified rocks were formed by watery agents in the same way that the Laurentian rocks were deposited, and in which modern formations are being deposited now, and the gneissose structure of the most ancient formations was the result of an action which has at intervals characterised all geological time as late as the Eocene formations in the Alps and elsewhere.

The same kind of chronological reasoning is often applicable to igneous rocks. It was generally the custom, many years ago, to recognise two kinds of igneous rocks, viz., Volcanic and Plutonic, and this classification somewhat modified in details is still applicable, the Plutonic consisting chiefly of granitic rocks and their allies, which, though they have often altered and thrust veins into the adjoining strata, have never, as far as I know, overflowed in the manner of the lavas of modern and ancient volcanoes. Indeed, as far as I recollect, the first quoted examples of ancient volcanoes are those of Miocene age in the districts of Auvergne, the Velay, and the Eifel, and the fact that signs of ordinary volcanic phenomena are found in almost all the larger groups of strata was scarcely suspected. Now, however, we know them to be associated with strata of all or almost all geological ages, from Lower Silurian times down to the present day, if we take the whole world into account. Amongst them, those of Miocene date hold a very prominent place, greatly owing, doubtless, to the comparative perfection of their forms, as, for example, those of the South of France and of the Eifel. Their conical shapes,

[1] I must also, with much pleasure, advert to Professor Prestwich's inaugural lecture when installed in the Chair of Geology at Oxford in 1875, the subject of which is 'The Past and Future of Geology.'

and numerous extinct craters, afford testimony so plain, that he who runs may read their history. The time when they became extinct would doubtless amaze us by its magnitude, if it could be stated in years, but yet it is comparatively so recent that not all the undying forces of atmospheric degradation have been able to obliterate their individual origin.

It is, however, generally very different with respect to volcanoes of Mesozoic age, for though Lyell stated with doubt, that volcanic products of Jurassic date are found in the Morea, and in the Apennines; and Medlicott and Blanford consider that probably the igneous rocks of Rajmahal may be of that age, we must, perhaps, wait for further information before the question may be considered as finally settled. Of Jurassic age no actual craters remain. Darwin also has stated, on good grounds, that in the Andes a line of volcanic eruptions has been at work from before the deposition of the Cretaceo-oolitic formation down to the present day.

In the British Islands we have a remarkable series of true volcanic rocks, the chronology of which has been definitely determined. The oldest of these belong to the Lower Silurian epoch, as shown, for example, on a large scale in Pembrokeshire, at Builth in Radnorshire, in the Longmynd country west of the Stiper stones in Shropshire, and on a far greater scale in North Wales and Cumbria. Of later date we find volcanic lavas and ashes in the Devonian rocks of Devon, and in the Old Red Sandstone of Scotland. The third series is plentiful among the Carboniferous rocks of Scotland, and in a smaller way associated with the Coal-measures of South Staffordshire, Warwickshire and the Clee Hills. The fourth series chronologically is associated with the Permian strata in Scotland, and the fifth and last consists of the Miocene basaltic rocks of the Inner Hebrides and the mainland of the West of Scotland.

In the British Islands the art of geological surveying has, I believe, been carried out in a more detailed manner than in any other country in Europe, a matter which has been rendered comparatively easy by the excellence of the Ordnance Survey maps both on the 1-inch and the 6-inch scales. When the whole country has been mapped geologically little will remain to be done in geological surveying, excepting corrections here and there, especially in the earliest published maps of the South-west of England. Palæontological detail may, however, be carried on to any extent, and much remains to be done in microscopic petrology which now deservedly occupies the attention of many skilled observers.

Time will not permit me to do more than advert to the excellent and well-known geological surveys now in action in India, Canada, the United States, Australia, New Zealand, and South Africa.

On the Continent of Europe there are National Geological Surveys of great and well-deserved repute conducted by men of the highest eminence in geological science, and it is to be hoped the day may come when a more detailed survey will follow the admirable map executed by Sir Roderick Murchison, De Verneuil, and Count Keyserling, and published in their joint work, 'The Geology of Russia in Europe and the Ural Mountains.'

It is difficult to deal with the Future of Geology. Probably in many of the European formations, more may be done in tracing the details of subformations. The same may be said of much of North America, and for a long series of years a great deal must remain almost untouched in Asia, Africa, South America, and in the islands of the Pacific Ocean. If, in the far future, the day should come when such work shall be undertaken, the process of doing so must necessarily be slow, partly for want of proper maps, and possibly in some regions partly for the want of trained geologists. Palæontologists must always have ample work in the discovery and description of new fossils, marine, freshwater, and truly terrestrial; and besides common stratigraphical geology, geologists have still an ample field before them in working out many of those physical problems which form the true basis of Physical Geography in every region of the earth. Of the history of the earth there is a long past, the early chapters of which seem to be lost for ever, and we know little of the future except that it appears that 'the stir of this dim spot which men call earth,' as far as Geology is concerned, shows 'no sign of an end.'

The following Papers were read:—

1. *On the Laurentian Beds of Donegal and of other parts of Ireland. By* Professor Edward Hull, *LL.D., F.R.S., Director of the Geological Survey of Ireland.*

After a perusal of the writings of previous authors, and a personal examination made in the spring of 1881, in company with two of his colleagues of the Geological Survey, Mr. R. G. Symes, F.G.S., and Mr. S. B. Wilkinson, the author had arrived at the following conclusions.

1st. That the Gneissose series of Donegal, sometimes called 'Donegal Granite,' is unconformably overlain by the metamorphosed quartzites, schists, and limestones which Professor Harkness had shown to be the representatives of the Lower Silurian beds of Scotland ('Quart. Journ. Geol. Soc.' vol. xvii., p. 256). This unconformity is especially noticeable in the district of Lough Salt near Glen.

2nd. That the Gneissose series is similar in character and identical in position and age with the 'Fundamental Gneiss' (Murchison) of parts of Sutherlandshire and Rossshire, and is, therefore, like the latter, presumably of Laurentian age. That the formation is a metamorphosed series of sedimentary beds, has been shown by Dr. Haughton and Mr. R. H. Scott.

3rd. That the north-western boundary of the Donegal Gneiss is a large fault between the Laurentian Gneiss and the metamorphosed Lower Silurian beds, owing to which the older rocks have been elevated, and by denudation have been exposed at the surface.

4th. That the Cambrian formation of Scotland is not represented in Donegal, and that the unconformity above referred to represents a double hiatus, and is of the same character as that which occurs in Sutherlandshire, in the district of Foinaven and Ben Arkle, where the Lower Silurian beds rest directly on the Laurentian Gneiss.

5th. That Laurentian rocks may be recognised in other parts of Ireland, as in the Slieve Gamph and Ox Mountains of Mayo and Sligo, at Belmullet, and in West Galway north of Galway Bay, where the rocks consist of red gneiss, hornblende rock, and schist, &c., similar to those in Donegal; also possibly in Co. Tyrone, as suggested by Mr. Kinahan.

---

2. *On the Laurentian Rocks in Ireland.*[1] *By* G. H. Kinahan, *M.R.I.A., &c.*

The writer first mentioned that Cainozoic and Mesozoic rocks only occurred in the province of Ulster, while in the rest of the island there was a nearly continuous sequence of Palæozoic rocks, from the Coal-Measures down to the Cambrian, proved by the work of Griffith, Jukes, and their subordinates. He then pointed out that a recent attempt had been made to try and disturb their natural order, but that the new theory was founded solely on assertions that would not bear investigation.

He proceeded to observe that the geologists of the Pre-Cambrian school appeared to lay more weight on lithological evidence than that to which it was entitled, and in continuation he gave the localities for the oldest rocks in Ireland, with the reasons for and against the rocks being Laurentian. The localities are *Carnsore* or S.E. Wexford, where it was shown that although the rocks were lithologically similar to the Laurentians, yet they contained Cambrian fossils—*Galway, S.E. Mayo, Sligo, and Leitrim*—rocks that, from their lithological characters, were said to be Laurentian by Murchison, who recanted his statement when Harkness showed that stratigraphically this was an impossibility. These rocks occur on two zones, those on the highest being now said to be Laurentian—*Erris, N.W. Mayo*—very old rocks, about which nothing can be positively said, except that they are older than the associated metamorphic rocks, which are also of uncertain age. *Donegal, Londonderry, and Tyrone*—the Laurentian age of some of these,

[1] A paper on the subject of this abstract appeared in the *Geol. Mag.*, for Sept. 1881, p. 427.

years ago, was suggested by Jukes, while now it is positively asserted, but solely on lithological characters. The author pointed out that, although these rocks lithologically were very like Laurentians, they were more like Huronians, Logan's description of the latter being very suitable for those of Donegal. He also pointed out that it was unnecessary to make vague assertions, as the stratigraphical position of the rocks ought to be easily worked out, either by starting from the Pomeroy fossiliferous rocks, or from the fossiliferous rocks found in Donegal by Dr. King; but that, at the same time, the work must be much better and more correctly done than that in the neighbourhood of Pomeroy, where the unaltered fossiliferous beds are classed with those they lie on, although the latter were extensively metamorphosed, contorted, upturned, and denuded, prior to the fossiliferous rocks being deposited on them. *N.E. Antrim*—rocks supposed to be of the same age as the older rocks near Pomeroy (*Upper Cambrians*).

---

3. *Life in Irish and other Laurentian Rocks.* *By* C. MOORE, *F.G.S.*

The author drew attention to certain forms found by a microscopic examination of specimens of certain Laurentian and other Palæozoic limestone prepared by trituration, solution in acid, and washing. These forms were clearly those of organic structures, some apparently hairs and others feather-barbs. The author considered that he had taken precautions to eliminate sources of error, through admixture of foreign materials; and he was led to think that the organisms belonged to the rocks.

---

4. *On the occurrence of Granite* in situ, *about* 20 *miles S.W. of the Eddystone.*[1] *By* A. R. HUNT, *M.A.*, *F.G.S.*

The author stated that during the past year he had received four specimens of rocks from the English Channel, trawled by Mr. W. M. Bayne's fishing vessel, the *Pelican.* Of these, three were trawled as detached blocks, and were respectively a gabbro, an actinolite rock, and a diabase: the fourth was a fragment of granite brought up in October 1880, about 20 miles S.W. of the Eddystone, after the vessel had been about three hours fast in what the crew first supposed to be a wreck. This fragment, which is about two inches in thickness, shows a clean fracture, has marine organisms on both sides, and has undoubtedly been detached from a submarine rock. There is no absolute proof forthcoming that this rock is *in situ*, but from the fact that the fishermen knew of no rocks in the neighbourhood, it can scarcely be a large erratic lying uncovered at the bottom of the English Channel, as such an obstruction would soon be found out and avoided. If an erratic, and too large to be moved by the hauling gear of a 60-ton vessel, it must be buried in the sand, and in this respect differ from the detached blocks described last year, which lie strewn on the surface of the Channel bed to the southward of the Bolt and Start. In mineral composition this granite agrees with the gneiss of the Eddystone and the gneiss of the Shovel Reef in Plymouth Sound, all these rocks being composed of orthoclase and plagioclase, the two micas and quartz, without either hornblende or schorl. The fact that the Shovel gneiss does not alter the Devonian rocks of Plymouth, the author considered an indication that these typical Channel gneisses are of pre-Devonian age.

---

5. *Some Observations on the Causes of Volcanic Action.* *By* J. PRESTWICH, *M.A.*, *F.R.S.*, *Professor of Geology in the University of Oxford.*

Considerable difference of opinion still exists as to the cause of volcanic action. The hypothesis, however, generally accepted in this country is that of the late

[1] See 'Notes on the Submarine Geology of the English Channel,' *Trans. Dev. Assoc.*, 1881.

Mr. Poulett Scrope,[1] who considered that 'the rise of lava in a volcanic vent is occasioned by the expansion of volumes of high-pressure steam, generated in a mass of liquefied and heated matter within or beneath the eruptive orifice.' According to his view, the expulsion of the lava is effected solely by high-pressure steam generated in the volcanic foci, but no explanation is given how the water is introduced.

The objections to this hypothesis are—1st. That during the most powerful explosions, *i.e.* when the discharge of steam is at its maximum, the escape of lava is frequently at its minimum, and *vice versâ.*

2ndly. That streams of lava often flow with little disengagement of steam, and are generally greatest after the force of the first violent explosions is expended.

3rdly. That it is not a mere boiling over, in which case, after the escape of the active agent—the water—and the expulsion of such portion of the obstructing medium, the lava, as became entangled with it, the remaining lava would subside in the vent to a depth corresponding to the quantity of lava ejected; but the level of the lava, *cæteris paribus*, remains the same during successive eruptions. Of the important part played by water in volcanic eruptions there can be no doubt, but instead of considering it as the primary, the author views it as a secondary cause in volcanic eruptions.

All observers agree in describing ordinary volcanic eruptions as generally accompanied or preceded by shocks or earthquakes of a minor or local character, to which succeed paroxysmal explosions, during which vast quantities of stones, scoriæ, and ashes, together with volumes of steam, are projected from the crater. The violence of the explosions gradually decreases and they then cease altogether. The flow of lava, on the other hand, which commences sooner or later after the first explosions, is continued and prolonged independently. Ultimately the volcano returns to a state of repose, which may last a few months or many years.

Adopting the theory of an original igneous (but now in greater part solid) nucleus and of a thin crust, the author considers a certain fluidity of the former, or of a portion thereof, and mobility of the latter, to be proved by the facts of the case. The one and the other feebly represent conditions of which the phenomena of the rocks afford clearer and stronger evidence as we go back in geological time. It is estimated that a small quantity of central heat still reaches the surface and is lost by radiation into space. It is evident also that even the escape of liquid lava and steam from volcanoes, and of hot springs from these and other sources, must bring, in however small a quantity, a certain increment of heat from the interior to the surface, where it is lost. This must lead to some very slight contraction of the nucleus, and of re-adjustment of the external crust, in consequence of which the fused matter of the interior from time to time tends to be forced outwards. So far the author agrees with many other geologists. The additional hypothesis which he now suggests, he has, however, been mainly led to form by his researches on underground waters, and may be stated generally as follows:—

A portion of the rain falling on the surface not only of permeable and fissured sedimentary strata, but also of fissured and creviced crystalline and other rocks, passes below ground, and is there transmitted as far down as the permeable rocks range, or as the fissures in the rocks extend, unless some counteracting causes intervene. Those causes are the occurrence of impermeable strata, faults, and heat. The former two are irregular, the latter one is constant. The increase of temperature with depth being 1° Fahr. for every 50 to 60 ft., the boiling-point of water would be reached at a depth of about 10,000 ft., but, owing to the pressure of the superincumbent rocks, it has been estimated that water will retain its liquidity and continue to circulate freely to far greater depths, but a point will be reached where the tension of the heated water will equilibrate the pressure.

Very little is known of the substrata of volcanoes. Etna and Hecla apparently stand on permeable Tertiary strata, Vesuvius on Tertiary and Cretaceous strata, while in South America some of the volcanoes are seemingly situated amongst

[1] For reasons that will be apparent, the author does not discuss the chemical theory of Davy or the ingenious thermodynamical theory of Mallet.

palæozoic and crystalline rocks. Under ordinary circumstances, all the permeable strata and all fissured rocks become charged with water up to the level of the lowest point of escape on the surface, or if there should be an escape in the sea-bed, then to the sea-level, *plus* a difference caused by friction.

The extreme porosity of lavas is well known. All the water falling on the surface of Etna and Vesuvius (except where the rocks are decomposed and a surface soil formed), disappears at once, passing into the fissures and cavities formed by the contraction of the lava in cooling. Not only are these fissures filled, but the water lodges in the main duct itself, and occasionally rises to a height to fill the crater. Beneath the mass of fragmentary and cavernous volcanic materials forming the volcano, lies the original compact mass of sedimentary strata, &c. Owing to the fortunate circumstance of an Artesian well having been sunk at Naples, we know that under 735 feet of volcanic beds there are 787 feet of sedimentary strata consisting of alternating strata of marl, sands, and sandstones, some water-bearing, others impermeable. This boring passed through three water-bearing beds—one in the volcanic ashes, the second in the Sub-Apennine beds, and the third in the Cretaceous strata at the bottom. The water from the lowest spring rose 8 feet above the surface, or 81 feet above the sea-level.

It is well known that where the strata crop out in the sea-bed, the pressure of the column of inland water forces the fresh water outwards, so as to form freshwater springs in the sea, as at Spezzia and elsewhere on the Mediterranean coast. It is this fundamental hydrostatic principle which keeps wells in islands, and in shores adjacent to the sea, free from salt water, as in the Isle of Thanet. But though the head of inland water is sufficient to force back the sea-water under ordinary conditions, if the normal conditions are disturbed by pumping to an extent that lowers the line of water-level to below that of the sea-level, then the sea-water will flow inwards until an equilibrium is established.

When undisturbed, the underground fissures and cavities of the volcanic materials forming a volcano soon become filled by the infiltration of rain-water from the surface, while the strata on which they rest are charged, or not, with water, according as they are permeable or impermeable—following the usual laws affecting underground waters. No eruption of lava can then take place without coming in contact with these underground waters. The first to be affected will be the water in the cavities of the mountain and the crater. As the pressure of the ascending column of lava splits the crust formed in the vent subsequently to the preceding eruption, the water finds its way to the heated rock, and leads to explosions more or less violent. Further, as the fluid lava breaks more completely through the crust, and the mountain becomes fissured by the force and pressure of the ascending column, all the water stored in the mountain successively flows in upon the hot lava, and flashes off into steam. Thence those more violent detonations and explosions—those deluges of rain arising from the condensed steam—with which the great eruptions usually commence. As the more superficial waters lodged in the superincumbent lavas and ashes are exhausted, the springs in the deeper underlying sedimentary strata, cut into by the fissures through which the main ducts pass, come into play, and discharge their contents more or less rapidly into those ducts, where, when the water reaches the point, where the pressure permits, it flashes into steam and rises in vast bubbles of vapour to the surface of the lava. Of the quantity of this underground water some notion may be formed by the fact that the deepest of the three springs under Naples discharged, when first tapped, two cubic mètres (440 gallons) per minute. The water may pass in bodily in consequence of the powerful shocks and vibrations shattering the strata, and so causing masses of rock to fall in from the sides of the main duct, together with the water lodged in the beds; or it may pass in by capillarity, for it is well known that this state exercises a remarkable influence on the conditions of equilibrium on the two sides of a porous body, and M. Daubrée has shown that water will pass through sandstone against a pressure of steam greater than that of the column of water. The experiments were only carried to the extent of a steam-pressure of two atmospheres, but it was evident that the limits of the power were not reached. They further also showed that heat materially increased the transmitting power. There is reason therefore to suppose that water, under the considerable hydrostatic pressures that exist beneath volcanic mountains, and assisted by capillarity, may flow into the volcanic ducts with facility, especially when aided by the intermittent relief of pressure afforded by the rise and fall, or pulsations, of the column of lava.

As the underground springs also are exhausted by the expulsion of the large volumes of water (as aqueous vapour), another agent comes into operation. When, by the continuance of this action, the level of the underground waters in the sedimentary strata under the volcano is lowered to below that of the sea-level, so that their hydrostatic pressure is no longer equal to that exercised by the sea-water, the current becomes reversed, and instead of an outflow from the land, an inflow of salt water from the sea necessarily takes place through the same excurrent channels, and thus, taking the place of the displaced fresh water, finds its way to the volcanic ducts. Then, from the exhaustion of the fresh-water supplies and an impeded access of sea-water, the lava flows quietly and unaccompanied by the violent explosions which mark the commencement of an eruption. If, on the other hand, the sea-water gains access more freely through the more porous volcanic materials, it may help to maintain, as in Stromboli and Kilauea, a constant volcanic activity. In ordinary cases, however, when the inland waters, after the force of the eruption is expended, regain the ascendant, they again exclude the sea-water, and return to a state of equilibrium, which lasts until the strata are again disturbed and fractured by a renewed eruption of lava.

In conclusion, the author conceives that the first cause of volcanic action is the welling up of the lava, in consequence of pressure due to slight contraction of the earth's crust. Secondly, the fluid lava coming into contact with water stored in the crevices of the masses of lava and ashes forming the volcano, the water is at once flashed into steam, giving rise to powerful detonations and explosions. Thirdly, follows an influx of water from the underlying sedimentary strata into the ducts of the volcano; and, lastly, as these subterranean bodies of water are thus converted into steam and expelled, the exhausted strata then serve as a channel to an influx of sea-water into the volcano. A point is finally reached when, owing to the cessation of the powerful shocks and vibrations, and the excessive drainage of the strata, the flow of the lava is effected quietly, and so continues until the lava ceases to rise.

---

6. *The Connection between the Intrusion of Volcanic Rock and Volcanic Eruptions. By* Professor SOLLAS, *M.A., F.R.S.E.*

In a volcanic eruption there are concerned, first, the elevation of the lava column in the axial pipe of the volcano, and next the explosion by which the lava is ejected into the air. The author attempts to find a *vera causa* for the latter. Sorby's researches on included cavities prove that steam at a high tension must have been everywhere present throughout plutonic rocks when these were in a state of fusion, and the presence of steam in ejected lava is well known. Judd's researches show that plutonic rocks are in many cases the solidified remains of deep-seated lava from which volcanoes were supplied. It may therefore be shown that the axial pipe of a volcano is occupied by fused rocks permeated by steam, which is probably in a liquid state, and the tension of which at any point in the tube will depend on the hydrostatic pressure due to the lava column above it. Any sudden diminution of this pressure will lead to a sudden expansion of the steam, and so tend to produce a volcanic explosion.

The mere elevation of the lava in the volcanic pipe cannot directly produce a diminution of pressure, though an overflow at the surface of the ground would; but this infers that the overflow of lava should precede an eruption, which is not the case; hence the author concludes that an overflow of lava from the sides of the pipe takes place underground, and the pressure on the lava column being reduced beneath the point of outflow, an eruption follows. The abundant presence of intruded sheets and dykes of igneous rock, known to occur beneath volcanic cones, thus stands in close connection with the production of volcanic explosions.

FRIDAY, SEPTEMBER 2.

The following Papers were read :—

1. *On the Influence of Barometric Pressure on the Discharge of Water from Springs. By* BALDWIN LATHAM, *M.Inst.C.E., F.G.S., F.M.S.*

The author of this paper mentioned that it was alleged, by some of the long-established millers on the chalk streams, that they were able to foretell the appearance of rainfall from a sensible increase in the volume of water flowing down the stream before the period of rainfall. He had, therefore, undertaken a series of observations to investigate the phenomena, and he found, in setting up gauges on the Bourne flow in the Caterham Valley, near Croydon, in the spring of this year (1881), and selecting periods when there was no rain to vitiate the results, that whenever there was a rapid fall in the barometer, there was a corresponding increase in the volume of water flowing, and with a rise of the barometer, there was a diminution in the flow. The fluctuations in the flow of the Croydon Bourne, due to barometric pressure, had at one period exceeded half a million gallons per day. The gaugings of deep wells also confirmed these observations; for where there was a large amount of water held by capillarity in the strata above the water-line, at that period of the year when the wells became sensitive and the flow from the strata was sluggish, a fall in the barometer coincided with a rise in the water-line, and under conditions of high barometric pressure the water-line was lowered. Percolating gauges also gave similar evidence, for after percolation had ceased and the filter was apparently dry, a rapid fall of the barometer occurring, a small quantity of water passed from the percolating gauges. The conclusion arrived at was, that atmospheric pressure exercises a marked influence upon the escape of water from springs. The increase in the flow of the water was attributed to the expansion and escape of the gases held by the water under low barometric pressure, which caused the water to escape more freely, while with high barometric pressure there was a condensation and inward flow of the gases which led to a retardation in the flow of the water.

---

2. *Glacial Sections at York, and their relation to the later deposits. By* J. EDMUND CLARK, *B.A., B.Sc., F.G.S.*

General Relation.—The York area chiefly consists of Glacial beds, which form the high ground and cover the various extensive low tracts more or less remote from the Ouse. Glacial depressions have been filled up with brick-earths, and, in exceptional cases, peat-beds. Where the river channel is narrowed below the city, the crests of the banks are capped with gravels reaching on the left bank below the river-level.

Peat-beds.—Campleshon Pond and part of St. Paul's Square are peat-beds where depressions were elevated above the levels covered with brick-earth. The same explanation may apply to the peat at Messrs. Backhouse's nurseries. But Askham Bog, $1\frac{1}{2}$ miles long by $\frac{1}{2}$ a mile broad, at the far end of the Hob Moor deposits, seems to be over a depression so deep and remote that the clay deposits only partly filled it. Near Ouse Bridge a peat-bed 50 feet down, at Brett's Brewery, has been called Interglacial; but the beds above it cannot positively be asserted to be Glacial; for at the waterworks similar beds appear, in which plant-roots were detected 20 feet down. The beds are warpy brick earths, with some sand in the latter case.

Brick-earths.—At the Harrogate Signals, $\frac{1}{4}$ mile further north, the junction of the upper beds with Glacial (or probably Glacial) beds is seen; but the change is almost insensible, although very soon true boulder clays are exposed. The junction was seen better during the construction of the Foss Islands railway, the brick-clays at the edge of the marsh resting against an uneven surface of boulder clay, whilst for some distance an average of 5 feet of brick-earth covers a surface consisting of uneven boulder clay, half planed down and the hollows filled with sand.

At a few points bosses of boulder clay protrude even here through the upper bed, whilst elsewhere depressions are filled with brick-clays, now extensively worked.

Gravels.—The gravel beds at Fulford and on the opposite side of the Ouse are much alike. The latter, however, are placed higher. The beds are irregular, often roughly stratified, often with sand-beds and stones, from grit to boulders of a quarter-ton weight. The stones are precisely the same as those in the boulder clay; some limestone boulders are still striated. On both sides of the river, 25 feet down at one point in Fulford, a black band of manganese has been found yielding on analysis 60 per cent. of manganese dioxide. This looks like soot, encrusting usually the upper half of a layer of dry stones, one foot thick. The rest and adjacent beds are brown with the sesquioxide, whilst ferrous oxide comes just below.

At the gravel pits now being worked on the Bishopthorpe Road a metatarsal of *Ursus spelæus* (or of the grizzly) was found this spring. There seems to be no previous record of any carnivorous remains from this neighbourhood.

Glacial Sections.—The *deepest* glacial sections were made in drainage-work at the Friends' Retreat, in 1876, a drift, 650 feet long, cutting through the hill from N.W. by W. to S.E. by E. At the highest point this was 47 feet below the surface. Shafts were sunk every 50 feet. Nothing but glacial beds were met, tough boulder clays, gravelly beds, and sand-beds. The latter were variously inclined and much cut up, rarely continuing any great distance. Indeed everything pointed to the whole mass being made up of independent parts, heaped and piled against each other. The third sand-bed was struck at the fifth shaft, the tough clay having been remarkably dry and crumbly for a yard above it, although the shaft was flooded with water higher up. At the first tap into the sand there was a great escape of gas, scaring the workmen away altogether for the four or five days it lasted. The probable explanation is that the sand-bed was close sealed by the clay, with orifices only near the base by which water could enter or leave. In dry seasons the line of saturation falling below these, the sand was left dry, with air only between the grains. The previous season was very wet; the line of saturation was at least 15 feet above the top of the sand. The contained air, unable to escape, was compressed into the upper part and slowly forced upwards into the boulder clay above until released by the workman's pick. At least 7,000 feet of air must have come off, but probably much more.

Between Shafts VIII. and IX. boulders were encountered by the men too big to remove; they thought some must have been of a ton weight. The largest brought up weighed about 600 pounds, which is as much as any I have found *in situ* near York, except, possibly, one still to be seen on the Mount. Some of those in the Museum grounds must weigh more. Among other stones two lumps of coal were brought up.

The most extensive series of sections are those on the site of the New Goods Station. For this a level was obtained 4 acres or so in extent, and 3 to 12 feet below the old surface. Unfortunately there are no records of the sections made in this part. Starting from the lower level, a series of sections covering 2½ acres was obtained about the building, reaching in one or two points 14 feet lower. These were chiefly exposed in the cellarage at the east end; but drainage and foundation trenches gave sections of varying depth in all parts. From these it has been possible to draw up a pretty complete plan of the beds. In the S.W. part these prove to be alluvial sands and laminated clays, forming a thin coat over the glacial deposits. Only about 3 feet of soil were removed from the S.W. corner, the depth increasing from this point. Looking at the ground-plan we are immediately struck by the regular strike of all the beds from S.E. to N.W. Examining the more complete sections at the E. end, they are found to consist of series of folds of clays, sands, and pebbles, resting against one central fold. The black and red boulder clays share this peculiarity with the sands. In these last it is more evident in two of the beds, from the pure black clay coming in bands and masses. The whole appearance suggests the work of an iceberg, ploughing up from the S.W. and pushing these beds before it. Diagrams and photographs were exhibited, to illustrate the characteristic points here indicated.

On the N. boundary of the area, 25 feet from the east end of these sections, 200 from the west, the beds are again much contorted. One section showed a mass of boulders and pebbles near the centre, looking as if tilted off an iceberg. Another, about 10 yards to the west, showed a sand mass, steep and angular, as if it had been deposited in one frozen lump. At another section, 200 yards east, behind the passenger station, contorted beds were again well shown, with layers of boulders, gravels, &c. Sands among them were very false-bedded.

The stones found, though including many from the Lake District, chiefly come from the Carboniferous beds of the West Riding. Limestones are usually scratched and often beautifully polished. At all the places mentioned occasional specimens occur from Lias and Oolite beds, so that an easterly drift must have sometimes counteracted the prevailing set from the west.

The main glacial beds approach nearest to the Purple Boulder Clay of Messrs. Searles v. Wood and Harmer. Floating ice, however, rather than the *moraine profonde* of an ice-sheet, seems best to account for the mixture of tough boulder-clays with beds of boulders, gravels, and current-bedded sands. At most sections there are indications that the upper glacial beds belong to a second glaciation, less severe than the principal cold period.

The post-glacial deposits are worked to depths of 30 feet and more; in the river-bed they may exceed 50 feet. The river is now 60 or 70 feet above its pre-glacial bed, and probably 40 or 50 above the level to which it first cut down in the opening of the post-glacial epoch.

---

3. *On the Bridlington and Dimlington Glacial Shell-beds.* *By* G. W. LAMPLUGH.

In a section recently exposed in the cliff north of Bridlington, the 'basement' boulder clay was seen to enclose masses of smooth tough clay, light blue or dark bluish-black in colour, mixed in places with a coarse yellowish-green sand. None of these masses were large, and most were squeezed out so as to form streaks or lenticular patches. Nearly all contained shells, some of which were unbroken, but more were crushed, and the fragments dragged apart as if by shearing. Foraminifera were also present. The well-known bed, a few hundred yards to the south, from which the Arctic shells were obtained, seems, from the description given, to have been a similar, though larger, mass. Of the twenty-eight species of mollusca collected from these patches, four are not included in the published lists of the Bridlington shells; viz. *Rissoa Wyville-Thomsoni*, *Menestho albula*, *Leda tenuis*, and *Leda lenticula*.

The surrounding boulder clay also contains many shells, chiefly fragmentary, derived apparently from the same source, as under many of the unbroken valves there still remains a little coarse sand, and of the twenty-five species identified, only one species and one variety are not included in the published list, viz: *Pecten opercularis* and *Mya truncata*, var. *Uddevallensis*.

At Dimlington, near Spurn, the same shelly boulder clay is again seen, and contains similar patches of mingled sand and clay, with broken and unbroken shells. Of the twenty-six species obtained from this locality, all except two are included in the Bridlington list. The exceptions are *Thracia pubescens* and *Cardium Grœnlandicum*.

In Filey Bay, on the beach opposite the village of Keighton, another of the same shelly blue boulder clay was seen, containing similar clay streaks with crushed shells.

This bed forms part only of the 'basement clay' of Messrs. Wood and Rome, as those gentlemen have included in their division a massive grey chalky boulder clay, with very few shell-fragments, which irregularly overlies the shelly clay at Dimlington, but is not seen at Bridlington.

As the shelly clay extends to low water both at Bridlington and Dimlington, its thickness and the character of the underlying beds are unknown.

It appears to be the remains of an arctic sea-bottom, which was first covered with fine glacial mud and then ploughed up and destroyed by ice.

4. *On Sections of the Drift obtained from the new Drainage Works of Driffield.*[1] *By* J. R. Mortimer.

The plan and sections of the Driffield drains cover an area of forty acres, showing a length of six miles. The noticeable feature is the complicated interbedding of sand and gravel with boulder clay.

The gravels consist almost entirely of waterworn pieces of chalk of small size, though foreign boulders are occasionally present; and the fact that both chalk and boulders are frequently found standing on end shows that they must have been dropped into their position by ice.

The dovetailing of the chalk gravels with the boulder clay is confined to a narrow zone, bounded by the chalk hills on the one side, and on the other by a series of mounds and ridges, distant from the chalk one mile at Bridlington, and five at Hull. The mounds are not moraines, but due, the author thinks, to the melting of stranded ice-rafts bearing sand and gravel. They exhibit every variety of false bedding, due to rearrangement by tides, and are capped by an unstratified boulder clay. The remarkable features shown in the sections are due to ice action —the land ice bringing down fresh supplies of chalk—the sea-borne ice ploughing up the clays and preventing the escape of the gravels. Many instances can be given of chalk crushed and removed by ice.

The author considers that an ice-cap covered the chalk hills, filling up the valleys, and preventing subaërial denudation, and that the drift which fills up old preglacial valleys in the neighbourhood of the present coast never extended far inland, as no trace of it is to be found in any of the dales.

In tracing the position of the chalk gravel, the author calls attention to the striking fact that chalk boulders south of Hornsea contain *black* flints, which are never found in the Yorkshire chalk, and which must have come from Norway. The flints north of Hornsea are more of the Yorkshire type, and were probably derived from Flambro' Head.

---

5. *On the Subsidences above the Permian Limestone between Hartlepool and Ripon. By* A. G. Cameron, *Geological Survey of England and Wales.*

In this paper attention is drawn to the numerous forms of shrinkages of the land-surface, often extending to considerable depths into the rocks beneath, observable over the top of the Permian rocks betwixt Hartlepool and Ripon.

As a general explanation of their origin, it is suggested that where the underground water, flowing over the limestone surface, reaches the margin of the sandstone, it receives a check, whereby it accumulates, forming a chain of dams or pools along the line of junction of these rocks.

As denudation proceeds, hollows form above and below, until ultimately the phenomenon of the pits appears.

This being so, 'the water bubbling and frothing all over' is explained without calling in the aid of river-action.

Allusion is made to the Home Farm Colliery accident at Hamilton, N.B., in February 1877, through a subsidence in the gravelly alluvium of the Clyde; also to the recent subsidences at Blackheath, near London; and to the extensive caverns in the hematite districts of Furness.

---

6. *The Glacial Deposits of West Cumberland. By* J. D. Kendall, *C.E., F.G.S.*

The extent, form, and inner nature of these deposits were first described, a number of new and important facts being brought forward on the distribution of boulders both in the boulder clays and in other glacial deposits.

[1] This paper will be printed *in extenso* in the Proceedings of the Yorkshire Geological and Polytechnic Society.

The conclusions arrived at from the facts are—

1st. That the boulder clays were formed in the sea, partly by glacial action and partly by icebergs. The occurrence of boulders from distant localities—often in very different directions—in a matrix partaking of the character of the underlying rocks, is explained in an entirely new way.

2nd. That the middle sands and gravels are the result of marine and river action combined.

3rd. That the mounds of sand and gravel occurring in the mouths of valleys were accumulated by floating ice, from pre-existing deposits.

A new explanation was given of the occurrence of boulders at higher levels than the rocks from which they were derived.

---

7. *On Simosaurus pusillus (Fraas), a step in the Evolution of the Plesiosauria. By* Professor H. G. SEELEY, *F.R.S., F.L.S.*

The author gave a detailed description of the skeleton of Simosaurus, recently discovered in the Trias near Stuttgard, and briefly noticed and figured by Dr. Oscar Fraas. He then drew special attention to the differences from plesiosaurus, especially in the form of the pectoral arch, and in the characters of the fore and hind limbs.

Hence we see in Simosaurus a land animal in process of adaptation to natatory conditions. The width of the humerus appears to have relation to a lateral flexure of the fore limb, by which the bone became the chief agent in movement on land; and as the land-progression was not entirely lost, the fore arm had not become reduced in length to the plesiosaurian form. The small number of phalanges was similarly explained. The hind limb was discussed to show how it might assume like characters with the fore limb. The author concludes that the plesiosauri were originally land animals, and that their ancestors and affinities must be sought in Simosaurus, Nothosaurus, and allied types of amphibious Triassic reptiles.

---

8. *On a restoration of the skeleton of Archæopteryx, with some remarks on the differences between the Berlin and London specimens. By* Professor H. G. SEELEY, *F.R.S., F.L.S.*

The author, by tracing the forms of the bones from a photograph, arranged the skeleton so as to represent a bird which stood about ten inches high. The head has a post-occipital process similar to that which occurs at a separate bone in the cormorant; the neck is curved forward; the tail reached almost to the ground, and the limbs were carried exactly as in birds.

The Berlin fossil certainly belongs to a distinct species; almost as certainly to a distinct genus, and is probably the type of a distinct family of saururous birds. The author did not name the fossil, believing that duty to devolve upon the writer who may hereafter figure and describe this fossil.

SATURDAY, SEPTEMBER 3.

The following Papers were read:—

1. *On Asterosmilia Reedi, a new species of coral from the Oligocene of Brockenhurst, Hants. By* Professor P. MARTIN DUNCAN, *F.R.S.*

The museum of the Philosophical Society of York contains, thanks to the industry and generosity of Mr. Reed, a very interesting series of corals from Brockenhurst in the New Forest. Nearly all the species of the Oligocene coral fauna of that part of England, which were described in the publications of the Palæontographical Society, are present in Mr. Reed's collection, and there is one form in addition which is very remarkable.

Description of the corallum.

The corallum is simple, cup-shaped, narrow, and rounded at the base, which was free, and it is wide and open, and rather triangular at the calice, whose margins are slightly inverted, except at the angles.

An epitheca exists. The costæ, where visible, are alternately large and small, but always slender. There is much exotheca between the costæ.

The calice is rather deep, and, judging from the structure of the base of the corallum, the columella is small and tubercular. The septa are numerous, not exsert, slender, unequal, granular at the sides, and there are four cycles and part of a fifth.

The pali are distinct, bilobar, rounded or arched above, and as broad as the septal ends, and granular. There are three crowns or circles of pali: one before the primary, and others before the secondary and tertiary septa, and the septa of higher orders have none; the largest are in one circle and the smallest in another, which is placed remote from the columellary space. The circle of pali before the tertiary septa is intermediate in position between the others. The height of the specimen is two centimètres, and the extreme breadth of the calice is 2·5 centimètres.

Remarks.—This is an aporose coral with the very rare combination of exotheca, endotheca, and pali—a combination not hitherto observed in any British Island coral, which only occurs in the coral fauna of the miocene of the Antilles, and in the fauna of the deep sea of the Caribbean region.

In investigating the corals from the miocene reefs of the West Indies, I described a form which had the exothecal and endothecal structures and pali, and placed it in a new genus, Asterosmilia ('Phil. Trans.' 1867). A year or two since the late Count de Pourtalés proved that the genus is extant, for he dredged up a species and described it.

But the species of the genus Asterosmilia had only pali before two orders of septa. The presence of a third crown of pali is not, according to the analogy of other genera, sufficient to remove the coral form, obtained at Brockenhurst, now under consideration, from the genus Asterosmilia (*mihi*), and I therefore name the species after the geologist to whom the museum at York is so greatly indebted—*Asterosmilia Reedi.*

The other species of coral which were associated with *Asterosmilia Reedi* in the deposit at Brockenhurst belong to such very tropical genera as Madrepora and Solenastræa, and the members of the family Eupsamminæ, whose modern representatives are both deep and shallow water forms.

I would especially draw attention to the dimensions of a specimen of *Madrepora Anglica*, nob., from Brockenhurst, for it is a large piece of a vigorously-grown perforate coral whose modern representatives only flourish in less than twenty fathoms, and in a temperature of the sea higher than the mean of 72° F. Such a Madrepora would now grow on a shallow bank or on the flank of a reef of coral. The Brockenhurst specimens of Madrepora have been rolled and worn since death, but not for any great distance, for the tissue of the coral was fragile in the extreme. But the Asterosmilia and one specimen of an Eupsammine especially, do not indicate, from their state of preservation, that they have been rolled. They lived and died not far from where they were found, and they may have lived at any depth within or beyond twenty fathoms. Probably not far below the lowest springtide level was their habitat, but it is possible that they may have had a deeper one.

In conclusion, it is necessary to remind those geologists who take an interest in the physical geography of the period when nummulites were dying out, that vast structures of Oligocene coral limestone were then forming in Northern Italy, and the Austrian Alps, and that a great coral fauna prevailed west of the Indus.

2. *On the Strata between the Chillesford Beds and the Lower Boulder Clay, 'The Mundesley and Westleton Beds.' By* Professor J. PRESTWICH, *M.A., F.R.S.,*

Where a particular series of strata presents, in adjacent and conterminous areas, markedly different palæontological and lithological characters, it may be sometimes convenient, as in the case of the 'Reading and Woolwich Series,' to give them a double geographical term, indicative of the localities where each type is well-developed, and its relation to the overlying and underlying strata well shown.

The beds between the Chillesford Clay and the Lower Boulder Clay present such a series. Its exhibition on the coast of Norfolk, although very limited, is accompanied by special palæontological features, that have caused it to be divided into the number of local beds which have been described by Trimmer, Green, Gunn, Wood, and Harmer, the author, Reid, Blake, and others. It includes the 'Laminated Clays,' the 'Elephant' and 'Forest beds' of Gunn, the 'Bure Valley Crag' of S. Wood, the 'Westleton Shingle' of the author, and the 'Rootlet-bed' of Blake. Without reverting at present to the exact correlation of the several beds in the Norfolk area, respecting which there is still some difference of opinion, the author suggests that they should all be included under a general term founded on the localities where, on the one hand, their varied palæontological characters are exhibited, and on the other, where their peculiar lithological characters are well-marked—characters which the author proposes to show, in another paper, have a very wide range, and serve to mark an important geological horizon affecting some interesting questions of local physical geology.

The Mundesley beds were described by the author in 1860, and consist of alternating beds of clay, sands, and shingle, some containing freshwater and others marine mollusca, with a forest-growth and mammalian remains at their base; and again in 1871, when he included them in his Westleton group (No. 5 of his sections), which he showed at that place to consist entirely of great masses of well-rounded shingle, with intercalated seams containing traces only of marine shells. Seeing the inconvenience of attaching the same term to the two very distinct series of beds, and that it may conflict with other local terms, the author now proposes to group this series under the term of 'The Mundesley and Westleton Beds,' indicative of their stratigraphical position in Norfolk, and of characters in Suffolk which serve to identify them in their range westward and inland to considerable distances beyond the Crag area. At the same time, it may be convenient, for brevity, to use one term only in speaking of typical cases.

---

3. *On the Extension into Essex, Middlesex, and other Inland Counties, of the Mundesley and Westleton Beds, in relation to the age of certain hill-gravels and of some of the valleys of the South of England. By* Professor J. PRESTWICH, *M.A., F.R.S.*

The author gives in this paper the result of observations commenced more than 30 years since, but delayed publication partly in consequence of the complexity of some of the phenomena. As mentioned in the preceding paper, a peculiar group of land, freshwater, and marine beds occupy, on the Norfolk coast, a zone between the Chillesford Clay and the Lower Boulder Clay. As we proceed southward, the land and freshwater conditions are gradually eliminated, and marine conditions there alone prevail. Poorly marked as the marine evidence is in Suffolk, this evidence is entirely wanting further inland, and we have only levels, superposition, and structure to rely on in correlating the fragmentary outliers into which these beds finally resolve themselves. Again on the coast of the Eastern counties, this group forms a nearly level plane but little above the sea-level, resting everywhere on an undisturbed or very slightly eroded bed of Chillesford Clay, and being succeeded, with but slight evidence of denudation, by the Lower Boulder Clay, or by the Glacial sands and gravel; whereas, as it trends inland, it attains a considerable elevation above the sea-level, passes unconformably over the older Tertiary strata, and was, with them, subjected to a great amount of denudation before the deposition of the succeeding Glacial series. On the other hand, the old land, which seems to have extended westward from the Norfolk coast, is now in great part below the level of the German Ocean. Further, whereas the succeeding Glacial beds all show a drift from northward to southward, this is the only case that has come under the author's notice of a marine drift from southward to the northward.

The Westleton Beds, in their more typical aspect, consist of quartzose sands full of flint-pebbles, almost as much worn and as numerous as in the Lower Tertiary sands of Blackheath. With these are mixed—(1) A good many small white and rose-coloured quartz-pebbles; (2) Pebbles of Lydian stone; (3) Large flattened pebbles of a light-coloured quartzite; and (4) Rolled and worn fragments of Lower Greensand chert. It is the presence of these, and especially of the last, that constitutes so marked a feature of these beds, and together with the absence of pebbles and rock-fragments of northern origin, serves to separate them from the Inter-glacial sands and shingle with which in places they come into juxtaposition.

The author then proceeds to trace the beds through Essex, and gives a series of railway sections showing these beds, exhibiting usually the appearance of a white gravel, with intercalated ochreous beds, and reposing on a very eroded surface of the London Clay. Near Clare there is a pit in which they exhibit oblique lamination, and might, apart from the want of fossils, be mistaken for a Crag section. Near Braintree, a remarkable section was exposed in the branch railway to that town. It showed these beds much faulted, overlain irregularly by a darker bed full of the New Red Sandstone quartzite pebbles, and the whole covered by indenting Boulder Clay.

In following the beds further westward they undergo further modification. Certain characters remain, however, persistent, and on these we have to rely. 1st, the shingle is composed essentially of chalk-flint pebbles, becoming less worn as we approach the southern limits of the deposit; 2ndly, it often becomes much mixed with flint-pebbles and subangular fragments of compact sandstone derived from the underlying Tertiary strata; 3rdly, the Greensand chert and ragstone fragments often so increase in numbers as to constitute a large portion of the gravel. They are worn and subangular, and the chert is identical with the chert of the Lower Greensand of Kent and Surrey; 4thly, the pebbles of white and rose-coloured quartz, of Lydian stone, and of whitish quartzite become rarer, and in places are wanting. The Lydian stone and some of the small quartz pebbles may be derived, with the chert, from the Lower Greensand, but this will not account for the great number of quartz pebbles found in the Eastern counties. The quartzite pebbles are as large but lighter-coloured and more ovoid than those of the New Red. They probably have drifted from a continental area on the east, the author having found similar beds in parts of Belgium. 5thly, the absence of northern drift.

It is to this age that the author would refer the drift gravel capping some of the higher ground in Epping Forest, and also the Middlesex hills around Barnet and Southgate, and extending thence in outliers to the range of hills between Hertford and Hatfield, South Mimms and St. Albans, and possibly as far north as Tyler's Hill, near Chesham. Ranging further westward, it forms a small capping on Horsington Hill, near Harrow, which serves to connect it with its high level on Bowsey Hill, near Henley-on-Thames. Southward, it caps St. George's Hill, near Weybridge. Approaching its southern boundary, this drift becomes less worn and passes into a subangular flint-gravel, capping several of the hills south of the Thames. At Cherry Down, near Windsor, it consists in large part of subangular fragments of chert and ragstone. It caps Hungary Hill, near Farnham, another hill west of Cæsar's Camp, near Bagshot; Meadow Down, near Guildford; and Pobly Hill, near Dorking, and some others. To this period may possibly be also assigned the gravel on the top of Well Hill (if not older), near Chelsfield, Kent; and some sand and gravel on the top of the cliffs near Minster, in the Isle of Sheppey.

The author reserves for another occasion the description of the beds next in order; but he would mention here, that the Boulder Clay and some Glacial gravels occupy in Herts and Berks a lower horizon than the Westleton Beds. It would therefore appear that, while the eastern area was submerged, and the strata followed in regular succession upon a surface which did not undergo denudation, the southern and western area was slowly elevated, and underwent partial denudation before the Upper Boulder Clay was deposited. Previous to the period of the Westleton and Mundesley beds, it is probable that the deeper denudation of the Weald had hardly commenced. The northern part of this area was under the sea at the beginning of the Crag period (the Lenham Beds), and judging from the character of the beds at Well Hill, Cherry Down, &c., the author concludes that there was land south of this fringing shingle, whence the great mass of Chalk-flints and of Lower Greensand chert and ragstone must have been derived. The quantity of this *débris* serves to attest to the great mass of these strata that was subsequently removed from the Wealden area. After the rise of the more central and northern parts of the area over which the Westleton Beds extended, that area also underwent extensive denudation, and it was at this period that the great plain of the Thames Valley received its first outlines, although it was not until much later that the river valley received its last impress.

---

4. *A preliminary account of the working of Dowkerbottom Cave, in Craven, during August*, 1881.[1] *By* E. B. Poulton, *M.A.*, *F.G.S.*

Dowkerbottom Cave is 1,250 feet above the sea, between Arncliffe and Kilnsey. Its mouth is merely a fall in the roof of the cave, which stretches from either end of the fissure thus formed. The original mouth is not now visible, but is probably to be found at the foot of a slope to the south. During most of its course the chambers and passages of the cave are not separated by any great thickness of rock from the ground above, and thus other falls must be expected to occur. The eastern division of the cave is about 450 feet long and has three fine chambers separated by two passages—the first very short and the second very long. This division ends under high ground to the north-west, and the true mouth must be in the other or western division. The last chamber on the eastern side is characterised by mechanical deposits—blocks of limestone fallen from the roof, and a stiff brown clay beneath. In the other chambers and passages of both sides are chemical deposits—hard and soft stalagmite. The western division is smaller, but also contains three chambers and two passages. It must be about 250 feet long and contains various heaps of limestone blocks fallen from the roof, but no clay on the surface. In former workings by Mr. Farrer, Mr. Denny, and Mr. Jackson, the first chambers were explored, in their surface layers at least, and here were found the numerous metal and bone ornaments and implements, together with the bones of animals usually found (in the historic layers of Romano-British age) in caves. The second passages have also been worked, and part of the second chamber on the eastern side. Other parts of the cave appear to be quite untouched. The great difficulty in working the cave is the removal of the *débris* to prevent interfering with further work. We therefore put up a windlass over the eastern entrance, and cleared a way for barrows through the talus below. Beneath the talus, the black earth, in which remains had been previously found, was seen, and many articles of Roman age were taken from it. Chamber III. was marked into parallels and these into squares. In the centre we sunk a shaft and passed through the following layers:—

(1) *Romano-British layer*, a black earth with pottery, ornaments, &c., and numerous bones, from one to nine inches thick. (2) *Hardish stalagmite*, about six inches thick: in one place containing the bones of a dog or small wolf. (3) *Soft stalagmite*, four inches thick. (4) *Hardish stalagmite*, six inches thick. (5) *Soft stalagmite*, two feet six inches thick. (6) *Stiff brown clay* with large

[1] A paper on the whole work at the Cave has been read (Oct. 12), before the Geological and Polytechnic Society of Yorkshire, by Mr. Poulton, and will be found in the Proceedings of that Society.

angular blocks of limestone fallen from the roof firmly imbedded in it. This layer was eight feet deep, as far as we saw it. The last two feet are laminated and contain smaller blocks. At the depth of about twelve feet from the surface we came to part of the solid limestone floor or side of the cave, sloping steeply downwards. There were no indications of a change in the nature of the deposit at the junction with the limestone, and the clay appears to extend much deeper than the level at present reached. Thus below the stalagmite purely mechanical deposits succeed, and no limestone blocks are found above this horizon, although the stalagmite has been removed over a large part of the floor of the chamber. No traces of a fauna have been as yet found below the first hardish stalagmite; indeed all the deposits passed through below the stalagmite indicate the former presence of a still lake in which the great thickness of clay slowly accumulated. Further work was stopped by the heavy rain which flooded the shaft dug in the clay. It is interesting to note that the former condition of Chamber II. is identical with the present state of the third chamber in the preponderance of mechanical over chemical deposits. The change from mechanical to chemical deposits was probably produced by a change from accumulation in still water to accumulation in running water. Possibly also the absence of blocks fallen from the roof in the stalagmite may be due to the bicarbonate of lime contained in the water, which percolated through the roof, cementing together the limestone blocks. The absence of this cement when the clay was deposited may be due to the absence of solvent power in the water which then percolated through the roof. For no carbon dioxide would be evolved from a soil deficient in organic matter—as the soil covering the Yorkshire hills for a period long after the Glacial period must have been. I wish to express my best thanks to J. R. Tennant, Esq., of Kildwick Hall, Leeds, and to J. R. Eddy, Esq., of Carleton, Skipton, on behalf of the Duke of Devonshire, for their kind permission to work the cave, and especially for the kind help and advice that Mr. Eddy has given all through the work. I also wish to heartily thank those gentlemen who have helped me in the work itself.

MONDAY, SEPTEMBER 5.

The following Reports and Papers were read:—

1. *Seventh Report on the Circulation of the Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations of England, and the Quality and Quantity of the Water supplied to towns and districts from these formations.*—See Reports, p. 309.

2. *Third Report on the Tertiary Flora of the North of Ireland.*—See Reports, p. 152.

3. *On the Formation of Coal.* *By* EDWARD WETHERED, *F.G.S.*, *F.C.S.*

The author first reviewed the researches of Hutten, Göeppert, MacCulloch, Sir James Hall, Sir W. Logan, and Dr. Dawson, and then summed up the conclusions now entertained as to the formation of coal, as follows:—

First, That the beds of fireclay which underlie all seams of coal, represent the original land-surfaces upon which the coal-forming vegetation grew. 2nd. That the Stigmaria found in the underclays were the roots of that vegetation, which implies that the plants were of the Lepidodendroid order. 3rd. That the vegetation grew near the mouths of great rivers, in swampy ground, and there underwent submergence; changes then took place which converted the vegetable matter into coal. 4th. That the change of coal from one variety to another, even in the same seam, is the result of metamorphism, and is indirectly caused by the contortion of the surrounding strata, whereby facilities for the escape of gases evolved by the vegetable decomposition have been produced.

The author's exceptions to the above were—1st. That coal was not formed from vegetation of the Lepidodendroid type, and that therefore the stigmaria found in the underclays are not the roots of the vegetation which gave rise to the coal, unless it was from the spores of these plants, which the author considered by no means proved, though coal undoubtedly did contain spores. 2nd. That the varieties of coal, and the change which sometimes takes place in one and the same seam, are not due to metamorphism, nor are they dependent upon the contorted state of the surrounding strata, but arise from the greater or less chemical decomposition of the vegetable mass, influenced by the circumstances under which it was submerged.

The reasons which had led up to these conclusions were:—1st. That we have proof of other vegetation during the coal-period besides the Lepidodendroids, but their roots have not been preserved, owing to their being of a more perishable nature than the Stigmaria. 2nd. Beds of underclay are frequently met with, full of Stigmaria, but are not followed by seams of coal. 3rd. Coal must have been formed from a compact mass of vegetation, such as could not have been produced by large trees (as the Lepidodendroids were) growing *in situ*. The uniform thickness and comparative freedom from inorganic contamination, would demand a mass of vegetation into which only a limited amount of sediment could penetrate. 4th. The finding of a fossil tree standing *in situ*, upon which so much stress had been laid by some authors, is a rarity. Though the author had spent much time underground in collieries, and seen hundreds of fossil trees drifted into the position in which they have been found, he had only twice seen instances of them standing where they have grown. 5th. If seams of coal were formed from Lepidodendroid trees the tough bast layer would be easily detected, which has never been the case in any true bed of coal. 6th. If the Stigmaria found in the underclays represent the roots of the coal-forming vegetation, we should expect to find the fructifications immediately over the coal, which is not the case; with the exception of Cordaites (which in the author's opinion was a Reed), remains of the fossil flora are not found for the first two feet or so over the coal.

After a careful investigation underground of the conditions under which coal was formed the author has arrived at the following conclusions:—On the land grew the vegetation of the period, represented by the Lepidodendrons, Sigillaria, Calamites, &c. As the land sank and the waters encroached, the land vegetation gradually disappeared, but the roots remained in many cases, and those which offered the greatest resistance to decay are the ones preserved in a fossil state—hence the occurrence of Stigmaria. As the waters advanced, the ground would become swampy, and then we might expect to see spring up reeds, mosses, and other vegetation suitable to the changed condition; it is to vegetation of this kind that the author ascribes the formation of coal.

Reference was then made to the Presidential address of Professor Ramsay to the British Association in 1880, in which the recurrence of the same kind of incident through geological time was advocated. The author then asked, why the coal-formations of the Carboniferous period should be an exception, seeing that the modern lignites and deposits of peat were instances of coal in the process of formation. It was then pointed out that these deposits were not composed of large trees, but of a lower order of plants.

Coming to the varieties of coal and the change which sometimes takes place in this respect in one and the same seam, it was shown that the difference between bituminous and anthracite coal was, that the latter contained a greater proportion of carbon and a less amount of volatile matter than the former. It was then contended that if the decomposition of the coal-forming vegetation took place without being affected, to any extent, by minerals capable of oxidising the carbon, that a coal would be formed having a large proportion of carbon with a less proportion of volatile matter than is found in bituminous coals. The author explained this by briefly reviewing the process by which vegetable matter has been converted into coal. It chiefly depended upon the amount of oxygen which could unite with the carbon, forming carbonic acid, and the amount of hydrogen which could unite with the carbon to form marsh gas. By this process oxygen and, hydrogen would pass off in greater proportion than the carbon, thus increasing the proportion of the latter to the whole. If, however, the submerging waters placed in contact with the vegetable mass substances capable of supplying oxygen to the carbon, then there would be a decrease in the proportion of the latter, and what the author termed the 'fixed oxygen and hydrogen' would increase in proportion to the whole and give rise to a coal of a bituminous nature.

With a view of ascertaining whether the chemical composition of the beds overlying a seam of coal which has changed from bituminous to anthracite also changed, the Welsh 'nine feet' seam was selected, which near Cardiff is semi-bituminous and at Aberdare becomes anthracitic. Specimens of the overlying strata were selected from the two districts at each foot above the coal for five feet; these were analysed, and it was found that the beds from near Cardiff were considerably more argillaceous and, as a whole, less ferruginous than those at Aberdare. It would be rash to attempt to determine the exact chemical nature of the sediment deposited over the coal-forming vegetation in the two localities, as, with the exception of silicate of alumina, the silicates and other minerals would have undergone decomposition at the expense of the carbonic acid given off from the coal-forming vegetation. There was, however, a decided change in the beds of the two sections presented, which could not be ascribed to metamorphism. It rather appeared to point to the sediment containing different constituents, which must have had a very considerable effect on the vegetable mass. It was to this that the author was inclined to assign the change in the character of the coal.

---

4. *Preliminary Remarks on the Microscopic Structure of Coal.* *By* Professor W. C. Williamson, *F.R.S.*

At the two first meetings of the British Association at York and Oxford in 1831 and 1832, two papers were read on coal and coal-plants, by the late Henry Witham. Since that time comparatively little progress has been made in our knowledge of the structure and physical composition of coal. Many local and limited observations have been made by Dawson, Huxley, and others, but the results have been indefinite if not contradictory. The author aims at bringing our knowledge of coal to a more advanced state by commencing a systematic series of microscopic observations of the coals of the entire world so far as he can obtain possession of them. Many months of such observations have been devoted to the coals of Eastern Scotland and to those of South Wales. These inquiries, though so limited, have suggested the possibility of certain conclusions being ultimately arrived at; but at present they are only advanced as hypothetical ones—though they appear to be supported by the investigations already completed. A large proportion of the coals examined contains mineral charcoal or mother coal in various conditions; sometimes the fragments are gathered together in thick layers of considerable extent, at others they are thin and limited in their area. Frequently separate fragments are isolated in the bituminous mass which encloses them. In a large number of instances, portions of each fragment can readily be detached for microscopic examination, but in many cases the fragments have become so consolidated and blended with the mass of the coal as to be incapable of such separation. All these fragments exhibit a fibrous aspect when seen under low powers, as opaque objects, but under lenses of higher power and with transmitted light, they resolve themselves into two groups: one of these consists of fragments of what are more or less bast-like, prosenchymatous tissues, and bear the aspect of cortical structures. The others, on the other hand, belong to the fibro-vascular group of tissues, exhibiting in the same minute portion of a fragment various modifications of such tissues from those that are scalariform to fibres with bordered discs. The most numerous are such as approach the latter more nearly than the former type. These fibro-vascular structures bear no resemblance whatever to those of either Lepidodendroid and Sigillarian plants, or to those of ferns; they approach much more closely to the mixed forms seen in the Cycadeæ, to which group of plants they most probably belong.

Intervening between these layers of charcoal are layers of a wholly different character. These consist of the more bituminous portions of the coal which are separable into two elements—*i.e.* one or more forms of spores in varying, but most frequently vast, numbers, embedded in a matrix, usually of a dark brown colour when ground sufficiently thin to admit of light being transmitted through it. In most of the coals examined the spores are of two kinds, as shown by Huxley, Dawson, and others, the larger ones, which are macrospores, having even been figured by Witham in his work on the structure of fossil plants. The smaller ones are doubtless true microspores, and, as might be expected, are much more numerous than the macrospores.

A second and far less numerous group of beds occurs amongst the coals of Eastern Scotland. These are, the 'Paraffin,' 'Parrot,' or 'Gas' coals. So far as observations have proceeded, these coals display no signs of the presence of mineral charcoals, and they are entirely devoid of macrospores. On the other hand they are densely crowded with small spores undistinguishable from the microspores of the ordinary coals. Such examples also are much less laminated than are the heterosporous coals.

That the combined macrospores and microspores of these latter coals are Lycopodiaceous, there appears little reason to doubt. The nature of the spores in the Parrot or isosporous coals is much less obvious.

The nature of the brown plasma in which these spores are embedded is open to question. The author is inclined to think that it is the resultant of the vegetative tissues of the various Lepidodendroid and other cryptogamic plants which constituted the great Carboniferous forest, but which were much more liable to decay than were either their own spores or than the supposed Cycadean tissues which constituted the mineral charcoal. The author, however, only advances these views as working hypotheses, which may either be confirmed or modified as he advances with his investigations.

---

5. *On the Halifax Hard Seam.* *By* W. Cash, *F.G.S.*

The Coal-measures in the district around Halifax belong to the lower portion of the Ganister Beds, and, lying conformably upon the Rough Rock, which is the uppermost bed of the Millstone-grit series, attain, to the east of the town, a thickness of about 500 feet.

The measures are capped by the Elland flagstone, and the following is the order of superposition:—

	feet	inches
Elland Flagstone, Shales, &c.	120	–
80 yards band (coal)	—	6
Shales, &c.	110	–
48 yards band (coal)	1	–
Shales, &c.	36	–
36 yards band (coal)	—	7
Fire-clay	3	–
Shales, &c.	90	–
Shale with nodules containing fossil shells, fish-remains, and fossil wood (Dadoxylon)	10	–
Halifax Hard Bed (coal) with nodules containing fossil plant-remains with *minute structure preserved*	2	3
Ganister and Stigmarian roots	3	–
Shales, &c.	25	–
Middle band (coal)	—	6
Shales, &c. (including beds containing Anthracosiæ and Spiralis	35	–

Halifax Soft Bed (coal)	1	6
Shales, &c.	30	–
Bottom coal	—	6
Rough rock	Base.	

The two thickest beds, and indeed, the only workable beds of this series, are those known as the Halifax Soft Bed, which is about 18 inches thick, and the *Halifax Hard Seam*, which averages about 2 feet 3 inches. The latter bed is covered by some 10 feet of shales containing nodules, locally known as 'baum pots,' which are composed chiefly of carbonate of lime with a smaller amount of carbonate of magnesia, oxide and sulphide of iron, sulphates of soda and potash, and silica; the nodular concretions are very hard, and often coated with iron pyrites. When they are broken up they are usually found to contain fossil shells, (Nautilus, Orthoceras, Goniatites, Aviculopecten, &c.). Sometimes also fish-scales, and fossil-wood (Dadoxylon). The bed underlying these shales is the *Halifax Hard Seam*, and consists of an impure coal containing numerous nodules of similar composition to those which are found in the overlying shales, but containing in the place of fossil-shells the remains of plants only. These remains consist of stems, roots, rootlets, branchlets, sporangia, spores, &c., mixed together confusedly; but so exquisitely is the minute structure preserved, that on preparing thin sections of portions of the 'coal balls' for microscopic examination the most delicate organs are exhibited as clearly as in the section of a recent plant; the cell-walls of the tissues having been carbonised, and their cells themselves filled with carbonate of lime.

The great number of new forms, described from this bed by Professor W. C. Williamson, have thrown no small light on some of the difficult problems of Carboniferous Palæo-botany.

Among the most important organisms found in this bed the following may be cited:—

Astromyelon, Asterophyllites, Calamostachys Binneyana, Calamites, Lepidodendron Harcourtii, Lepidodendron selaginoides, Favularia, Sigillaria, Stigmariæ, Lyginodendron, Dadoxylon, Diplyoxylon, Kaloxylon Hookeri, Rachiopteris duplex, R. Oldhamia, R. cylindrica, R. aspera, R. Lacattii, R. tridentata, Cardio-carpon, Lagenostoma ovoides, Oidospora anomala, Sporocarpon tubulatum, Traquaria, Peronosporites antiquarius, Stomata (possibly of Cordaites?) &c. &c.

Perhaps the last addition of interest to this important local fossil flora is a fragment of a fossilised stem or branchlet which differs in some important particulars from anything previously met with. It consists of a central pith surrounded by a narrow zone of vascular or fibro-vascular tissue, outside which is a cambium ring, followed by a comparatively thick cortex. This cortex has a very peculiar organization, which, among living plants, is only met with in such aquatic forms as *Myriophyllum*, *Utricularia*, and a few others. The cortical structures of the fossil specimen agree most with those of *Myriophyllum*; and though in the present state of fossil botany we dare not suggest an affinity between them, it is at least deserving of record, that the organization of this stem bears a very close resemblance to the stem of a plant which ranks so high in the vegetable kingdom. In honour of Professor W. C. Williamson, F.R.S., who has done so much to elucidate the organization of Carboniferous plants, Mr. Hick and I propose to designate our specimen *Myriophylloides Williamsoni*.

---

6. *Researches in Fossil Botany.* *By* James Spencer.

During last winter I discovered two new spore-bearing capsules in the coal-ball material of the Halifax coal strata.

1. One of these contained some of the spores described by Professor W. C. Williamson, under the name of *Zygosporites brevipes*.

This sporangium forms another link in the history of these remarkable spores, and indicates that they are of lycopodaceous origin, and that they probably belong to some unknown form of Lepidodendroid plant.

It is of an oblong oval form, and about $\frac{1}{66}$ of an inch in breadth, by $\frac{1}{25}$ of an inch in length. The contained spores are of the usual kind.

2. New sporangium, containing minute fringed macrospores.

The other sporangium contains an undescribed species of tetraspores. It is of the same form as the one containing Z. brevipes, but very much smaller, being only $\frac{1}{100}$ of an inch in breadth, by $\frac{1}{50}$ of an inch in length. The contained spores are very minute and covered with hair-like appendages. They resemble the large fringed macrospores, so common in the same material, but they are more of a triangular, cockle-shell form. Minute as they are, several hundreds being probably contained in each sporangium, they are as perfect in form and as beautifully preserved as it is possible for them to be. What are these spores? Judging from their peculiar form and fringe-like appendages, I think it much more probable that they are macrospores than microspores, and that they belong to some unknown form of Lepidodendron.

3. A new fossil fungus.

The fact of the existence of fungi among the plants of the coal-measures is now well established. I have upwards of fifty microscopical preparations containing these fossil parasites. Peronosporites antiquarius is one of the most common forms, and is chiefly found in the fossil ferns and in the lepidodendra. Its mycelia may be often seen crowding the large vessels in the centre of the fern-stems and sending off branches among the surrounding parenchyma, where its spores sometimes occur in abundance. Its resting and other spores, along with those of cystopus and other forms, occur plentifully in many sections of the coal-ball material. Some of my sections of Lyginodendron contain numbers of spore-like bodies, which greatly resemble starch-grains, but the fact, that many of them have short thread-like tails, proves that they are not starch-grains. In the longitudinal section of a calamite I have found them associated with true mycelia. In one case there are two branching mycelia, each occupying the centre of one of the long tube-like vessels, with only a single vessel betwixt them, and surrounded by the spore-like bodies (haustoria). In its appearance and habits this fossil fungus is almost exactly like that of the recent species, Cystopus candidus. I have no doubt that it is a cystopus, and if not the identical species C. candidus, it is at least a near relation. I propose to give the fossil fungus the provisional name of Cystopus carbonarius.

---

7. *Notes on Astromyelon and its root.* *By* James Spencer.

This fossil plant is one of the new genera which have been described by Professor W. C. Williamson, F.R.S. It was so named from the star-like form of its pith; but since the name was given, many specimens have been found, especially in our Halifax beds, differing widely from the typical form, so that the name has now to be applied to specimens which have no pith, and to others in which the starlike aspect is by no means apparent. A transverse section of the stem bears a striking resemblance to that of the calamite, but there are several important differences between the two, which need not now be entered into. The transverse section of a typical specimen is composed of a woody zone formed of a number of wedge-shaped bundles, the spaces between these bundles and the centre being occupied by the pith. There are two principal forms of variation from the normal type. One of these has a structure not unlike that of the pine, and the pith is reduced to a very small speck, containing only a few small cells. The other variety has a large central cavity, which assumes various forms, and which are evidently due to the original structure and not to irregularities in fossilization. In many of these no pith is present; in others only a small portion remains. It is very probable that the absence of the pith in many cases is due to its destruction before or during fossilization. In many of these specimens the wedge-shaped bundles are absent, and the ligneous zone assumes a homogeneous structure. There is also a very great variety in the vessels forming the bundles, often even in the same plant, which gives to transverse sections a beautiful appearance.

A complete stem is seld m met with, the bark being generally absent, but in several of my sections this peculiar structure is well shown. It consists of a large-celled parenchyma of very loose texture, and may be divided into an inner and outer bark. The inner portion is formed of three or more rows of brick-like cells surrounding the woody zone, while the outer epiderm is formed of one or two rows of very large cells having a thick outer wall, the whole structure being little better than an epidermal layer, and of a very perishable nature. The roots of these beautiful plants have not yet been described, but I have good reasons for believing that the specimens I am now about to describe belong to them.

Professor Williamson has described two very singular plants from the Lancashire coal-field, under the generic name of Amyelon. One of these he has shown to be the root of Asterophyllites. This root appears to be rare in our Yorkshire coal-strata, but the other, *A. radicans*, is not unfrequently met with. I have lately found one or two new forms of these pithless roots, which appear to be closely allied to the latter species. One of these has a solid vascular cylinder consisting of radiating laminæ, the outer vessels of which are the largest, the vessels gradually becoming smaller as they approach the centre. Laminæ of small vessels and medullary rays intermingle at the circumference with laminæ of large ones; but as they converge towards the centre many of them coalesce with one another, so that even there the vessels do not become so small as they otherwise would do, and thus preserve an open network arrangement which gives the plant a very striking appearance. The bark, of which only a small portion is preserved, is almost identical in structure with that of Astromyelon.

The other root has a much smaller central axis, but it presents a striking difference, in the fact that its large-celled thick bark is nearly always present. I have many specimens of this root, and the majority have the bark fairly preserved. The structure of its vascular cylinder more nearly resembles that of *Amyelon radicans* than that of the other does; but the vessels are, as a rule, much smaller, and they are *barred* in the radial sections, while those of *A. radicans* are *reticulated.* While writing, both these plants are before me, and the difference in their vascular cylinders is most striking, especially in respect to the markings on the vessels, and also in respect to the beautiful state of preservation of the bark in my plant and its absence in the other. The bark is about as thick as half the diameter of the woody cylinder, and is composed of an inner layer of delicate mural parenchyma, and an outer epiderm of large cells, but of very irregular size, the middle portion being a combination of the two forms. Sometimes the structure is composed of large cells of more uniform size.

The next problem to solve is, to what plants do these roots belong? As the result of a very careful examination of a large series of specimens, I have come to the conclusion that they are the roots of Astromyelon. It would extend this abstract too far to go into the subject fully, but I may mention two or three of my reasons for coming to this conclusion. In the first place, the large open cells and vessels of these plants are exactly what one would expect to find in the root of Astromyelon, just as we find the vessels of the vascular cylinder of Stigmaria agreeing with those of the ligneous zone, in the Lepidodendra. The very young forms of Astromyelon largely partake of the character of these roots. In longitudinal sections the vessels in both plants are identical. In the radial sections of both, the vessels are seen to be *barred.* The structure of the bark is also identical in both stem and root, and lastly I have invariably found the two associated in the same material. Being uncertain whether these two roots are merely different forms of one species, I propose to unite them provisionally under the name of *Amyelon radiatus.*

---

8. *On the Palæozoic Rocks of North Devon and West Somerset. By* W. A. E. Ussher, *F.G.S., Geological Survey of England and Wales.*

The author gave a brief introductory outline of the different opinions which had formerly been entertained respecting the structure of North Devon and West

Somerset. The subject-matter of the paper is a very concise description of the areas and extension of the divisions into which the Devonian rocks are separable upon stratigraphical grounds. The area treated of is embraced in sheets 20, 21, 26 and 27 of the Ordnance Maps. Of these, the Devonian rocks in sheets 20 and 21 had been mapped in detail by the author, whilst in the other sheets their relations had been carefully ascertained. The paper is little more than an index to the notes made by the author in prosecuting his researches in the stratigraphy of the Devonian area.[1]

The classification adopted is as follows:—

LOWER DEVONIAN	FORELAND GRITS	Red and purplish grits, fine-grained, and in places siliceous.
	LYNTON BEDS	Grey, even-bedded and jointed grits, grey schists, and schistose grits with films of calcareous matter.
MIDDLE DEVONIAN	HANGMAN GRITS	Coarse white quartzose, red-speckled grit, in and upon red and grey rather fine-grained grits associated with shaly and slaty beds.
	ILFRACOMBE SLATES PASSING INTO MORTE SLATES	Grey and silvery slates and shales with arenaceous films, and impersistent bands of limestone passing upward into pale greenish unfossiliferous quartzose slates.
UPPER DEVONIAN	PICKWELL DOWN BEDS	Indian-red slates upon red, green, and grey grits, with local purple slate basement-beds passing into the Morte Slates.
	BAGGY BEDS	Green slates with *Lingula*; brown micaceous grits with *Cucullæa*; the positions of these horizons are apparently reversed near Wiveliscombe.
	PILTON BEDS	Bluish and greenish grey argillaceous slates, with occasional thin films of limestone and masses of grit (as at Braunton, &c.)

The Foreland Grits occupy an area (superficial) of 30 sq. miles, extending from Countesbury to Dunster. They are faulted against the Lynton Beds, by a great fault, which can be distinctly traced; but where the latter are entirely cut out by it near Luccott Hill, the faulted junction between the Foreland and Hangman Grits is very vague, owing to the imperfect nature of the surface evidence. At Oare, the Foreland Grits are overlain by Lynton Beds on the north side of the fault.

The Lynton Beds occupy an area of about 14 sq. miles; they do not appear to the east of Luccott Hill; their junction with the Hangman grits is perfectly conformable, and near Trentishoe there is a very gradual passage.

The Hangman Grits form the range which includes Dunkery Beacon, also the whole northern part of the Quantocks. Their relations to the Ilfracombe Slates are much complicated by faults around Croydon Hill and on the Quantocks; and the prevalence of grits in the Ilfracombe series, whilst indicative of lithological assimilation, makes the boundary rather indefinite.

The Ilfracombe and Morte slates occupy a larger part of the Devonian area than any other division. Their lithological characters vary when traced into the Brendon and Quantock districts. Their junction with the Pickwell Down Beds is seldom affected by faults, and in West Somerset usually presents a perfect lithological passage through green and purple slates.

The Pickwell Down Beds in North Devon form a perfectly defined conformable junction with the Baggy Beds, Indian-red being contrasted with green slates. From North Molton to Wiveliscombe, the relations of the Upper Devonian beds are much complicated by faults.

The Baggy Beds are well-marked between Baggy Point and Stoke Rivers, but further east they are only locally distinguishable, owing to disturbances and the

[1] *Geol. Mag.*, for Oct. 1881, No. 208, p. 441.

presence of grits in the Pilton Beds. Near Dulverton (Witherwind) both the Cucullæa and Lingula Beds are distinguishable, but near Wiveliscombe the fossils have been found in reverse positions, the Cucullæa zone being under the Lingula slates.

The Pilton Beds are the most fossiliferous beds in the Devonian Series; their junction with the Culm-Measures appears to be a palæontological one near Dulverton, but the nature of the evidence along the junction is, as a rule, very unsatisfactory. Faults prevail near Morebath, but from Clayhanger eastward the junction appears to be perfectly conformable, following a feature line.

---

9. *The Devono-Silurian Formation. By* Professor E. HULL, *LL.D., F.R.S.*

The beds which the author proposed to group under the above designation are found at various parts of the British Isles, and to a slight extent on the Continent. The formation is, however, eminently British, and occurs under various local names, of which the following are the principal:—

ENGLAND AND WALES.

Devonshire.—'The Foreland Grits and Slates,' lying below the Lower Devonian beds ('Lynton Beds').

Welsh Borders.—'The passage beds' of Murchison, above the Upper Ludlow Bone bed, and including the Downton Sandstone, and rocks of the Ridge of the Trichrag. These beds form the connecting link between the Estuarine Devonian beds of Hereford (generally, but erroneously, called the 'Old Red Sandstone,' and the Upper Silurian Series).

South-east of England (Sub-Cretaceous district).—The author assumed, from the borings at Ware, Turnford, and Tottenham Court Road, described by Mr. Etheridge, that the Devono-Silurian beds lie concealed between Turnford and Tottenham Court Road on the south, and Hertford on the north.

IRELAND.

South.—'The Dingle Beds,' or 'Glengariff Grits and Slates,' with plants and fucoids, lying conformably on the Upper Silurian Beds, as seen in the coast of the Dingle promontory, and overlain unconformably by either Old Red Sandstone, or Lower Carboniferous Beds. They are from 10,000 to 12,000 feet in thickness.

North.—'The Fintona Beds,' occupying large tracts of Londonderry, Monaghan, and Tyrone, resting unconformably on the Lower Silurian beds of Pomeroy, and overlain unconformably by the Old Red Sandstone, or Lower Carboniferous Beds; from 5,000 to 6,000 feet in thickness.

SCOTLAND.

South.—Beds of the so-called 'Lower Old Red Sandstone' with fish and crustaceans, included in Professor Geikie's 'Lake Orcadie, Lake Caledonia, and Lake Cheviot,' underlying unconformably the Old Red Sandstone, and Lower Calciferous Sandstone, and resting unconformably on Older Crystalline rocks. Thickness in Caithness about 16,200 feet.

The author considered that all these beds were representative of one another in time; deposited under lacustrine or estuarine conditions; and, as their name indicated, forming a great group intermediate between the Silurian, on the one hand, and the Devonian, on the other. He also submitted that their importance, as indicated by their great development in Ireland and Scotland, entitled them to a distinctive name, such as that proposed.

---

10. *On Evaporation and Eccentricity as Co-factors in Glacial Periods. By the* Rev. E. HILL, *M.A.*

As the temperature rises, the evaporation from water grows; grows rapidly, and with continually increasing rapidity. If at a steady temperature there be a steady amount of evaporation, then the result of fluctuations in temperature will be to augment the amount of evaporation. Hence, if with a steady heat-supply there be a given amount of evaporation, fluctuations in that supply will in like manner augment that amount. Or if fluctuations already exist, an increase in their extent will still further augment the amount. But increased eccentricity can increase the differences in the rates of heat-supply; also evaporation is equal to precipitation. Therefore under increased eccentricity the annual snowfall may be augmented without any accompanying increase of annual melting. Thus an uncompensated annual surplus of snow may be produced which will accumulate. The possible increase for fluctuations of a probable amount is calculated, and found to be appreciable and considerable.

---

11. *On the Discovery of Coal-Measures under New Red Sandstone, and on the so-called Permian Rocks of St. Helen's, Lancashire.*[1] *By* A. STRAHAN, *M.A., F.G.S., Geological Survey of England and Wales.*

The Trias has been penetrated, during the last few years, by three colliery shafts and three boreholes in the district bordering the St. Helen's and Wigan coalfields on the south. It was thinner than might have been expected, while the Permian formation was altogether absent. This latter formation was believed to underlie the Trias, but to be overlapped, so as not to appear at the surface, excepting at St. Helen's Junction, where a marl-bed, and a soft sandstone beneath it, 30 and 90 feet thick respectively, and supposed by Messrs. Binney and Hull to be Permian Marl and Lower Permian Sandstone, were found in a quarry and a well.

The Bold Hall Colliery shaft, at about 1 mile from the outcrop of supposed Permian rocks, proved the shale to maintain its thickness, but the sandstone to be 57 feet 9 inches only. The Coal-Measures were entered at 186 feet, and penetrated to a depth of 1,800 feet from the surface, when the Florida Mine was met with. The red staining, due to the Trias, extended to a depth of 365 feet in the Coal-Measures.

The Collins Green Colliery shafts, at the same distance from the boundary of the Trias, but three-quarters of a mile north-east of Bold Hall Colliery, proved the shale to be 22 feet, and the sandstone 44 feet in thickness. The latter contained spherical concretions of iron pyrites, binding the grains of sand in their original position in the planes of bedding. The Coal-Measures were entered at 310 feet 10 inches, and penetrated to the Florida Mine, at 1,667 feet 7 inches from surface. They were red for 152 feet. The dip of the so-called Permian was to the south-east at 6°, that of the Coal-Measures at 10°.

The Haydock Colliery shafts (Lyme Pits), at the same distance from the boundary of the Trias, are 1 mile north-east of Collins Green. The shale and sandstone had diminished here to 9 feet and 7½ feet respectively. The Coal-Measures were penetrated to a depth of 97 feet 2 inches, or 413 feet 3 inches from surface. In the shafts of this and the Collins Green Colliery, the unconformity of the red sandstone and the Coal-Measures was clearly visible.

The above sections show that the so-called Permian Marl and Sandstone thin out gradually from west to east, the lower thinning out first, and not the upper, as would have been the case if they had been unconformably overlapped by the overlying beds. They thin out to the south also, as proved by a borehole near Farnworth, 3 miles south of St. Helen's Junction, which, after penetrating 124 feet of yellow and white sandstone, passed through 3 feet of red and white clay, 3 feet of red sandstone, and entered purple marls with bands of limestone, belonging to the Coal-Measures.

The so-called Permian Beds, though unconformable to the Coal-Measures, are quite conformable to the Trias, and are overlapped in consequence of an attenuation in themselves, and not through having suffered denudation before the Trias was deposited upon them. Considering also their lithological similarity to the Trias, it seems that they should be classed with this formation, rather than with the Permian.

[1] Published *in extenso* in the *Geological Magazine* for October 1881.

The Permian Rocks are probably absent west of Warrington, for two boreholes at Parkside and Winwick, commencing in the Pebble Beds, entered the Coal-Measures at 291 and 341 feet respectively, without encountering them. The Trias contained a bed of shale about 30 feet thick, and was based by soft sandstone with twig-shaped concretions of iron pyrites. Like the spherical nodules of Collins Green, these probably owed their origin to the action of Coal-Measure water, with sulphides in solution, acting on the colouring matter (peroxide of iron) of the Trias. The Coal-Measures consisted of purple and green marls, and at Winwick were associated with limestone. They, and the same beds found in the Farnworth boring, are precisely similar to the well-known Whiston Limestone, and like it contain the *Microconchus carbonarius*. These limestones are probably the equivalents of the Ardwick Limestone series in the Upper Coal-Measures of Manchester, and may be found to be underlain by representatives of the coal-seams which are found in connection with it. Without doubt, they must be everywhere underlain by the whole of the productive Middle Coal-Measures, but at a great and unknown depth, though there is reason to believe that the thickness of barren measures would be less in West Lancashire than near Manchester.

---

12. *On the Upper Bagshot Sands of Hordwell Cliff, Hampshire.* *By* E. B. Tawney, *M.A., F.G.S.*

The descriptions of former writers having been cited, it was found that there were two main views regarding the affinities of these sands, which occur in the cliff between Long Mead End and Beacon Bunny. The view formulated by the distinguished foreign geologists, D'Archiac, Dumont, Professor Hebert, and Professor C. Mayer, is that they are parallel to the upper sands of the Beauchamp (=Barton) period, and allied, therefore, to the marine Barton beds. This view is much the same as that of E. Forbes, and the Geological Survey, who called them the Upper Bagshot Sands.

Latterly Professor Judd has sought to revive the term Headon-Hill-Sands for them, presuming them to be most nearly connected with the Headon series, and extending the bounds of that series to receive them.

The author now gives a list of twenty-eight species obtained from the bed at Long Mead End; of these 35 per cent. are common to the sand and the Barton beds, but do not occur in the Headon series; while only 21·4 per cent. are common to the sand and Headon series, but do not occur in Barton beds. It is shown that this sand belongs to the zone of *Cerithium pleurotomoïdes*, Lam., and is exactly parallel to the sands of Mortefontaine, which belong to the same horizon, constituting the upper portion of the Beauchamp deposits. This is altogether below the *C. concavum* zone.

From these sands being intimately connected with the Barton beds in both areas, it is held that the term Upper Bagshot is the most fitting designation that has been proposed for them.

TUESDAY, SEPTEMBER 6.

The following Reports and Papers were read:—

1. *Ninth Report on the Erratic Blocks of England, Wales, and Ireland.* See Reports, p. 204.

---

2. *Report on Fossil Polyzoa.*—See Reports, p. 161.

3. *On 'Flots.'* *By* J. R. Dakyns, *M.A., Geological Survey of England and Wales.*

The word 'flot' is a miner's term for ore lying between the beds, or at certain definite horizons in the strata. In textbooks flots are generally called 'flats' or 'flattings.' They are of two kinds: (1) those connected with 'cross-veins'; (2) those connected with courses of dun limestone. Firstly, cross-veins are veins (generally mere spar veins on Greenhow Hill) which cross and intersect or shift the metal veins, but which often bear ore at their intersection with the metal veins. Where these cross-veins cut the flot-planes, ore is found. Secondly, similarly with courses of dun limestone. Dun limestone, so-called from its colour, is a dolomitized form of ordinary limestone. The dun lime occurs in beds or irregular masses, or more frequently in dyke-like courses, running N.N.W. and S.S.E. These courses are often several yards or even fathoms wide, and where the dun course crosses the flot-plane ore is developed along the joints between the dun and the white limestones.

Ore is not found along the flot-plane except at its intersection with the cross-veins or with the courses of dun limestone.

---

4. *Remarks upon the Structure and Classification of the Blastoidea.* *By* P. Herbert Carpenter, *M.A.*

The author and Mr. R. Etheridge, jun., who are preparing a joint Memoir upon the Blastoidea, have arrived at the following conclusions respecting the group.

It is very doubtful whether the genus *Pentremites* occurs at all in Britain. Some badly preserved fragments from the Devonian and the Scotch Carboniferous are possibly referable to it; but most of the Blastoids (besides *Codaster*) which occur in the Carboniferous Limestone belong to the genus *Granatocrinus*, Troost., which is represented by some seven or eight species.

Cumberland's *Mitra elliptica* is the representative of a new genus, distinguished by the eccentric position of the spiracles. *Codaster* is a true Blastoid, and not a Cystid, as supposed by Billings. The slit-like openings of its hydrospires are nearly on the same level as the ambulacra, which do not conceal them at all. In the ordinary Blastoids, however, they are below and concealed by the ambulacra, opening externally by pores at the sides of the latter. There are various intermediate forms between these two extremes, in which the hydrospiral slits are more or less concealed by the ambulacra, but are partially visible at their sides. It is proposed to group the species thus distinguished into a genus *Pentremitidea*, which is represented in Britain by the little *Pentremites acutus*, Sowerby, in Belgium by *P. caryophyllatus*, and in Spain by *P. Pailleti*, De Verneuil, for which last the name *Pentremitidea* had been already proposed by D'Orbigny. An arrangement of this kind has been already suggested by Billings.

The discoveries of Rofe, Wachsmuth, and Hambach, respecting the perforation of the lancet-piece by a longitudinal canal, are confirmed. This canal probably lodged the water-vessel, which must have been devoid of any tentacular extensions, as in some Holothurians, and in the arms of certain *Comatulæ*. Respiration was effected, however, by means of the hydrospires. The pores usually found at the sides of the ambulacra were not the sockets for the attachment of the appendages, but led downwards into the hydrospires, serving to introduce water, which made its way out through the spiracles. The genital ducts probably opened into some portion of the hydrospires, as they do into the closely similar structures of the *Ophiuroidea*, and the ova were discharged through the spiracles. Billings' statements are confirmed respecting the existence in many species of a single or possibly double row of jointed appendages along each side of the ambulacra; but these appendages are not homologous with the pinnules of the *Crinoidea*.

In perfect specimens the peristome is covered in by a vault of small polygonal plates, any definite arrangement of which is rarely traceable. Extensions of this vault were continued down the sides of the ambulacral grooves, which could thus be closed in completely and converted into tunnels, as in recent Crinoids.

The classification of the Blastoidea must depend entirely upon morphological principles. Mere differences in the relative sizes of the calyx plates are of very little systematic value; and differences in the numbers of side plates on given lengths of the ambulacra are absolutely worthless. On the other hand, the structure and relative positions of the hydrospires and spiracles are morphological characters of much systematic value.

---

5. *On the Characters of the 'Lansdown Encrinite' (Millericrinus Prattii, Gray, sp.)* *By* P. Herbert Carpenter, *M.A.*

The 'Lansdown Encrinite' is a species of *Millericrinus* (*M. Prattii*, Gray, sp. = *Apiocrinus obconicus*, Goldfuss) from the Great Oolite on the top of Lansdown, near Bath. It is remarkable for the very great variation in the characters of its stem and calyx. The former may reach 50 mm. in length, and consist of 70 discoidal joints; or there may be less than 10 joints, the lowest of which is rounded off below, and its central canal closed up. Various intermediate conditions may occur between these two extremes, while in some specimens there may be only 2 to 4 stem-joints; and in one case the whole stem is represented by a slightly convex imperforate plate on which the basals rest. This specimen, taken by itself, would be naturally regarded as a *Comatula* of advanced age, in which the cirrhus-sockets had disappeared from the centro-dorsal just as they do in the recent *Actinometra Jukesii.* The general appearance of the calyx is very similar to that of *Pentacrinus Wyville-Thomsoni* from the North Atlantic. But it is remarkable for the number of small intercalated pieces which it may contain. The basals are frequently separated from one another, or from the radials, by minute plates which, while regularly developed all round the calyx in some specimens, are entirely absent in others.

The nearest allies of *M. Prattii* seem to be *M. Munsterianus*, var. *Buchianus*, and *M. Nodotianus.* It stands on the extreme limit of the genus, connecting it with *Pentacrinus* on the one hand, and with the free *Comatulidæ* on the other. It is thus a synthetic type, as would naturally be expected from its geological position; for it is probably the earliest known species of the genus, except perhaps for two doubtful Liassic forms, which are known only by isolated plates and stem-joints.

---

6. *On the Lower Keuper Sandstone of Cheshire.* *By* A. Strahan, *M.A., F.G.S., Geological Survey of England and Wales.*

This paper deals with some of the results of the re-survey of parts of Cheshire, which have been already described in detail in the Geological Survey Memoirs 'On the Neighbourhood of Prescot' (3rd edition), and 'On the Neighbourhood of Chester.' Several sections, of which the best are at Runcorn and Frodsham, show that there is a strong and constant division between the Waterstones and the Keuper Basement Beds. These were formerly classed together under the name of Lower Keuper Sandstone, but, so far as the re-survey has been carried, are now distinguished on the maps. The old and new classifications may be compared as follows:—

Old Classification	New Classification
Keuper Marl	Keuper Marl
Lower Keuper Sandstone	Waterstones
	Lower Keuper Sandstone or Basement Beds

The Basement Beds, which form bold escarpments, consist of courses of hard building-stone with partings of soft sand, and a considerable thickness of soft current-bedded sand at top, distinguished by the name of the Frodsham Beds.

The courses of building stone are conglomeratic, and rest on eroded surfaces. The Frodsham Beds are precisely similar to the soft upper and lower subdivisions of the Bunter.

The Waterstones, on the other hand, are allied to the Marls in every respect, even the sandstone-beds being easily distinguishable from those of the Basement Beds. The striking contrast between the Waterstones and the Basement Beds is well shown at Runcorn and Frodsham, where deep-red shales rest direct upon the current-bedded sands of the Frodsham Beds. Upwards the Waterstones pass quite insensibly into the Red Marls, and like them, contain ripple-marks, sun-cracks, so called rain-pittings, and the casts of rock-salt crystals. The last-named appear first in the Waterstones.

The Waterstones, like the other subdivisions of the Trias, vary rapidly in colour. They are generally red, but near Kelsall are white, with green shales. The Basement Beds at Helsby are brown, but at Manley are white; at Delamere brown again, but once more white in the Peckforton Hills. The Frodsham Beds change from red to white in a few yards in the railway cutting at Runcorn, and again near Frodsham and Overton. The Upper Mottled Sandstone goes through every possible variation between red, white, and yellow, at Beeston Castle. These changes show that no dependence can be placed on colour as a means of identification.

In Lancashire, previously surveyed by Mr. De Rance, the base of the Marls had been drawn at this line below the Waterstones, no subdivision of the Waterstones from the Marls being possible, owing to Drift. The section in the Orrell railway is similar to that at Runcorn, and the Basement Beds here and at Ormskirk are of the same character as in Cheshire. In Liverpool the same sequence has been made out by Messrs. De Rance and Morton.

Near Nottingham the same line has been observed by Mr. Aveline ('Geol. Survey Memoir,' 2nd edition). Though the Basement Beds are thin, and in places absent, the Waterstones are well-developed. Mr. Shipman ('Nottingham Nat. Soc. Ann. Rep.' 1880) remarks on this overlap, and states that there is an appearance of erosion between the Waterstones and the Basement Beds. The same observer mentions the marked contrast presented by the Waterstones to the Basement Beds at Alton in Staffordshire.

The line therefore is persistent over a large area. The notion that there was a perfect passage from the Basement Beds into the Marls arose from incorrect mapping, by which the Waterstones were placed sometimes in the one, sometimes in the other subdivision. At this horizon also the principal overlap in the Trias takes place, for the Basement Beds thin out with the Bunter, but the Waterstones and marls run on beyond so as to rest on Palæozoic Rocks. The change in the character of the sediment, and the appearance of salt-crystals, show that at this period a change in the physical geography of the region took place, which led to tranquil deposition of sediment and the concentration of brine in land-locked basins.

This line at the base of the Waterstones was taken by Ormerod and others as the base of the Keuper, but in 1852 Prof. Hull drew the base below what then came to be called the Keuper Basement Beds, because, firstly, there was no sign of a break from this rock upwards; secondly, there was an apparent unconformity below it. It has been shown that the first of these reasons will probably not hold good. The second reason depends on evidence of unconformity which is not trustworthy. The apparent unconformity visible at Ormskirk ('Triassic Memoir,' p. 87) is an effect of current-bedding, and the evidence of denudation of the Bunter in South Lancashire and Cheshire rests on the identification of horizons in the Upper Mottled Sandstone by colour, which is now known to be untrustworthy. The appearances of erosion below the Basement Beds are equally strong at other horizons, for instance below the Pebble Beds in the middle of the Bunter.

Considering the strong lithological resemblance of the Basement Beds with the Bunter, and the similarity of its distribution, it must be reconsidered whether the importance of the line between them has not been over-estimated, and whether the line at the base of the Waterstones does not constitute a more important stratigraphical horizon in the Trias. It is proposed to distinguish in future the Waterstones from the Lower Keuper Sandstone, reserving the latter name for the sandstones and conglomerates, as typically developed in Cheshire.

---

7. *On a Discovery of Fossil Fishes in the New Red Sandstone of Nottingham. By* E. Wilson, *F.G.S.*

The author called the attention of the Section to a recent discovery of fossil fishes in the Lower Keuper Sandstone of England—a circumstance of sufficient rarity in itself, apart from any palæontological results, to deserve at least a passing notice.

During the construction of the Leen Valley Outfall Sewer in 1878, a remarkably interesting section was given by the tunnelling driven through Rough Hill, or Colwick Wood, near Nottingham, showing the lower beds of the Waterstones resting on a denuded surface of the 'Basement Beds' of the Keuper.

The lowest stratum of the Waterstones was a sandstone about a foot thick, with streaks of red and green marl, and a seam of pebbles at the base. The fishes occurred in this bed, and chiefly in a thin seam of red marl, overlying the pebbly seam at the very bottom of the Waterstones; they were present in large numbers, as if in a shoal, for a distance, in the line of section, of about 33 feet.

The specimens he obtained have been examined by several competent authorities, but unfortunately their state of preservation is so bad that nothing certain can be made out as to their precise zoological affinities. Dr. Traquair, however, believes that they probably belong to some species, new or old, of the genus *Semionotus.*

The occurrence of these fossils at the junction of two distinct sets of beds—the Basement Beds and the Waterstones—is probably not a mere chance coincidence. The characters of the preceding Keuper Basement Beds—false-bedded, coarse, grey sandstones and conglomerates with large fractured quartzite pebbles, and lenticular beds of red marl—prove them to have been formed during a period of great violence; while those of the Waterstones—regularly-bedded fine-grained yellowish sandstones and red marls covered with ripple-marks, sun-cracks, and pseudomorphs of common salt—show that they were formed in quiet and shallow waters. It appears pretty certain, then, that these fishes did not live in this area during the turbulent times of the Basement Beds, but came in when subsidence let in the quieter waters of the Waterstone epoch.[1]

---

8. *On the Rhætics of Nottinghamshire. By* E. Wilson, *F.G.S.*

The author gave a summarised account of the Rhætic series in Nottinghamshire. The Rhætic sections of this district already known to geologists comprise those at Gainsboro', Newark, and Elton. The author described several additional new sections in the Rhætics of the county—viz., at Cotham and Kilvington between Newark and Bottesford; at Barnstone, between Bingham and Stathern; the boring for coal at Owthorpe, near Colston Bassett; and the section at Stanton-on-the-Wolds, between Nottingham and Melton Mowbray. A list of the Rhætic fossils of Notts was given, and the presence of bone-beds noticed. The author could not agree with certain geologists that the green marls which are found beneath the Paper Shales in Notts (nor probably also the 'Tea-green Marls' of the West of England) belong to the Rhætic series, but took them to be Upper Keuper Marls, once red in colour, which had become discoloured by the downward infiltration of some deoxidising agents evolved during the decomposition of the organic matters of the fossils of the Paper Shales. For, in lithological character the

[1] It should be mentioned that the specimens were obtained under somewhat unfavourable circumstances, namely in the roof of a tunnel, several hundred feet from daylight, and after the rock had been defaced by smoke and dirt. The fossiliferous bed lies only a few feet below the surface of the ground, and if carefully opened from above better and perhaps identifiable specimens might very possibly be obtained.

green marls agreed with underlying beds in the Keuper, but differed markedly from the overlying Rhætics; then there was every appearance of a passage between the green marls and the underlying red and green marls of the Keuper; and, lastly, the green marls, like the rest of the Keuper marls, were practically unfossiliferous, while with the commencement of the Paper Shales we get the remains of an abundant, and distinctly marine fauna, in part Liassic.

---

9. *The Great Plain of Northern India not an old Sea-basin.* *By* W. T. Blanford, *F.R.S.*, *F.G.S.*, &c.

The author called attention to the distribution of land in the Indian peninsula, and to the intervention of a vast plain, traversed by the Indus, Ganges, and Brahmaputra, between the Himalayas and other hill ranges to the east, west, and north, and the more or less hilly tracts forming the peninsula itself. The plain varies in breadth from rather less than 100 to nearly 300 miles.

This plain has constantly been considered, both by geological and biological writers, as the basin of a great sea, that, in Tertiary times, and probably earlier, separated the Himalayan area from the land of the peninsula. Even in some geological descriptions by an officer of the Geological Survey of India ('Rec. G.S.I.' iii. p. 17) the older alluvial deposits of Bengal are classed as marine or estuarine.

On examining the evidence, however, there does not appear to be a single fact in favour of the sea having at any geological period occupied the Gangetic or eastern portion of the plain. On the eastern coast of India, near the shores of the Bay of Bengal, marine Jurassic strata are intercalated with certain beds containing land plants (Upper Gondwana) in several localities, and the same marine and similar plant-bearing beds are associated in Kattiawar to the westward. But in the only place on the edge of the Ganges plain where the plant-bearing beds are found, no marine fossils are met with. Some older beds of very low mesozoic or very high palæozoic age (Damuda) are found both north and south of the plain, and as they are river deposits, they may perhaps indicate that the intervening country was land when they were formed. At any rate no marine strata accompany them. A great thickness of nearly horizontal basaltic traps in the Khasi hills, east of the Gangetic plain, appears to be a continuation of the well-known Rajmahal traps, believed to be of Jurassic age, and if so, these volcanic rocks, which are undoubtedly of subaërial origin, must have extended across the plain north of Calcutta.

Again, marine cretaceous beds are found on the shores of the Bay of Bengal in two localities at least, and again in the Khasi hills to the eastward, showing that in all probability the coast line extended from one to the other, but no trace of such beds is known to occur on the edges of the Ganges plain.

Eocene (nummulitic) rocks of marine origin occur throughout the western margin of the Indus basin in Sind and the Punjab, and extend across the north of the latter to the spot where the Jumna leaves the Himalayas; east of this they are only found in one locality in Kumaon. Thence for 13 degrees of longitude not a trace has been discovered, nor do they recur until the Guro hills are reached. To the east of the Indus plain also nummulitic limestone occurs, but none is found along the southern side of the Ganges plain. Marine, oligocene, and miocene beds are met with as far north as the frontier between Sind and the Punjab, but have not yet been traced further north with certainty. Marine pliocene beds are only met with near the coast.

The distribution of marine Tertiary rocks therefore indicates that in Eocene times the sea occupied the whole Indus valley as far as the Himalayas, and an arm must have extended to the region now drained by the Upper Indus in Tibet, as nummulites have been found there; but there is no evidence of any sea having occupied the Gangetic or eastern portion of the plain. It is scarcely probable, if a nummulitic sea occurred throughout the whole Indo-Gangetic plain, that a fringe of nummulitic deposits, continuous over many hundreds of miles, should surround the western half, whilst not a trace has been found around the eastern half, except far to the eastward. In later Tertiary times the sea that occupied the Indus valley appears to have greatly decreased, and still further diminution of the marine area took place during the Pliocene epoch. As several species of land mammalia in the Pliocene Siwaliks are also found in Guzerat, it is manifest that land communication must have existed between the two areas.

All that is known of the Post-pliocene and recent deposits in the Indo-Gangetic plain leads to the same conclusion; no marine bed has yet been detected in them. Only a few borings have been made: but in one to a depth of 701 feet, at Umbala; in another 431 feet deep, at Bhiwani in Hissar (Punjab), and in a third 574 feet deep, at Sabzallsot in the Derajat, west of the Indus, no marine remains were discovered, and the beds traversed appeared to be all river-deposits. Still more extraordinary is the circumstance that the boring made at Fort William in Calcutta, to a depth of 481 feet below the surface, or 460 below the sea-level, passed through not a single undoubted marine deposit, whilst peat, freshwater shells, and mammalian bones were found, some of them at almost the greatest depths reached.

The whole of the negative evidence, and some direct evidence, is, therefore, opposed to the idea of the Gangetic plain having ever been occupied by the sea. The tract is evidently an area of depression filled up to above the sea-level, in all probability, throughout a long geological range of time, by the detritus from the surrounding mountains, and to a smaller extent from the hill tracts to the southward.

---

10. *The Gold Fields, and the Quartz-outcrops of Southern India. By* WILLIAM KING, *Deputy Superintendent (for Madras), Geological Survey of India.*

This paper was a *résumé* of the knowledge ascertained through the author's original survey of the Wainád gold field in 1874, and by the later surveys and examinations of others: also in his examination of the Travancore and other areas in the beginning of this year.

The geographical distribution of the gold areas is briefly treated of as being at Mangapet, on the Godávari river, near Dumbal, in the South Mahratta country, near Kolár, in Mysore, at Salem, in part of the Travancore State, and in the Nilgiri and Malabar country; and these are then reduced to the more important fields of Malabar (including Wainád and the Nilgiris) and Mysore.

Next follows a description of the rocks (Gneissic Series) of these two areas; and the extent, mode of occurrence, and constitution of the quartz-reefs traversing them. These gneisses are striking, in Mysore, northwards and southwards, and in Malabar north-east and south-west; while the reefs in both cases are running north-north-west to south-south-east, or thereabout, and are considered by the author to occupy the widened-out fissures of meridional jointing.

The reefs of Wainád are developed to a remarkable extent over a very large area of country; but their auriferousness is only displayed over a portion of this (mainly in south-east Wainád and in the adjacent low-country of Malabar), in a generally east-and-west belt, the reefs outside of this being fewer and only very locally auriferous. The leaders or offshoots of the reefs in this belt are strongly and numerously developed; and they and the 'casing' are rich in gold. It is these adjuncts of the reefs, and not the reefs themselves, which have been so extensively worked by the ancient miners. On the other hand, the reefs, as far as is known, do not as yet show any continued steadiness in their auriferousness, but may be said to be capriciously permeated with the precious metal. The gold of the reefs is pale-coloured and of about the 'touch' of standard gold; that of the 'leaders' and 'casing' is yellow gold and of superior quality.

The apparent distribution of the gold in a generally east-and-west belt over a country whose rocks are striking north-east and south-west, and the quartz-reefs of which are running north-north-west to south-south-east, and far beyond the limits of this belt, leads the author to speculate on a possible deposition of the gold subsequent to the formation of the reefs.

The peculiar quartz-outcrops of Travancore, supposed by many to be auriferous reefs, are next described, the author having, in his late examination of them for the Government of that State, been obliged to look on these as really beds of quartz-rock, or felspathic quartz-rock, associated and contemporaneous with the gneisses. A mere trace of gold has been found in a small sample of this rock; but none was found by ordinary hand-crushing and working. Neither are there any traces of old gold-workings in the area marked by these outcrops.

Lastly, the economic aspect of the Wainád field is considered. Mr. King does not see any good reason, on the total results obtained, to think that the average out-turn of gold will ever be appreciably more than that argued for from his original assays, namely, seven pennyweights to the ton. He also does not think that a paying return can be obtained on less than three pennyweights to the ton. Though very hopeful of the moderate and paying quality of the reefs, he is decidedly of opinion that the results obtained so far do not warrant the wild expectations which have been prevalent in England and India during the last twelve months; nor do they justify the enormous prices which have been paid for lands and concessions. Beyond the ultimate profitable working looked for by the author, there must be considerable delay (even for nine months more at least) before retarding conditions—such as the settlement of land tenure and mining rights, the obtaining of labour, and the getting of the machinery on the ground—can be overcome.

11. *On the Geology of the Island of Cyprus.* *By* R. Russell, *C.E.*

The physical features of the Island of Cyprus are two great mountain-chains, the axes of which are mainly parallel to each other. These two ranges are as distinct from each other in physical appearance as in geological structure. The southern or Troödos mountains are rounded in outline, and culminate in Mount Troödos, 6,340 feet above the sea-level. The northern, or Kerynia, mountain-chain rises up from the hummocky ground on both sides, as it were, in one great continuous wall-like cliff, its vertical crags and turret-like peaks projecting upwards to heights of more than 3,000 feet. The hummocky ground at the base of the precipitous cliffs has a most peculiar aspect. When looked at from above it resembles a bird's-eye view of Alpine scenery; when seen from the central valley it appears as if the whole area was covered with an immense number of small volcanic cones.

The central valley is flat when compared with the mountainous regions, but it is exceedingly irregular and broken. Flat-topped ridges and hills, and conical mounds, form a distinctive feature of this part of the island. The flat-topped hills rise quite abruptly from the low ground, and therefore show more prominently than they would otherwise do.

The rocks which occur in Cyprus may be classified as follows:—

POST-TERTIARY		Blown Sand; Alluvium (recent); Kavara (solidified surface); Raised Beach; Sand and Gravel (Old River Deposits); Calcareous Tufa and Traventine
TERTIARY . . .	Pliocene	Kerynia Rock; Nicosia Beds
	Miocene	Idalian Beds
SECONDARY . .	Upper Cretaceous .	Konnos
	Jurassic	Mount Hilarion Limestone
	Igneous Rocks	

The oldest stratified rock is doubtless the Mount Hilarion Limestone. This is a very hard, compact, crystalline limestone, generally of a dark blue colour. It is very difficult to distinguish between the bedding and jointing in this rock, and therefore equally difficult to determine the direction of the dip. Certainly the limestone is inclined at a high angle, and the general direction of the dip appears to be towards the north.

Above the compact limestone is a band of white schistoze limestone. This rock is fissile and jointy, splitting up into small fragments. It lies between the base of the Konnos, and the Mount Hilarion limestone.

'Konnos' is the term applied by the Cypriots to the rocks which occupy the country flanking the limestone crags. It is pronounced *Kornos.* The local name is adopted, as it means chalky-like, and therefore conveys some idea of the calcareous nature of the beds to which the term is applied.

The base of the 'Konnos' is a breccia composed of large angular fragments of limestone, this passes up into a conglomerate, and this again into beds of calcareous grey shales, with calcareous sandy bands, or beds of calcareous sandstone. The sandy bands are generally from a few inches up to two feet thick, but are very regular and continuous. The soft character of these rocks renders the work of subaërial denudation easy. The water, from the springs, and from the periodical rains, has cut deep and narrow gorges through the konnos, leaving sharp ridges between the ravines. It is the intersection of these ridges with each other which give to the districts which they occupy the appearance of a great series of small conical mounds.

On the north side of the range the dip is generally to the north. On the south side the inclination is also northwards for some distance, southwards from the central ridge, but afterwards the beds lie in a series of rolls, the axes of which are more or less parallel to the central axis of the mountain-chain. There are another set of undulations at right angles to the strike of the strata. Here then we have evidence that 'konnos' has been subjected to pressure, acting at right angles, and to pressure acting parallel, to the axis of greatest upheaval.

At the base of the Idalian beds on the flanks of the Troödos, there occasionally occurs a thin band of brown shale, in which are large concretionary lumps of dark-coloured chert.

This is followed by the white chalky rocks of the hills of Idalia, hence the name Idalian Beds. In general the Idalian Beds consist of thin-bedded white chalky-like flags much jointed. The layers are from one inch to one foot thick, but occasionally some of the bands are three or four feet in thickness.

Amongst these rocks are found irregular deposits of gypsum. The gypsum occurs as selenite in a matrix of gypsum, and as gypseous flags. The flags split up into thin layers and yield excellent pavement.

Near the base, the Idalian Beds contain bands of grey chert, and, in proximity to the volcanic rock, the white rocks assume a pinkish colour.

Any fossils which have been obtained from this series of rocks are of Miocene age, but still are scarcely sufficient to determine satisfactorily the exact age of the strata in which they are contained.

In the valleys of the rivers Morphu and Pidias, the Idalian Beds pass up into the shales and sands which I have named the Nicosia Beds.

The Nicosia Beds are well-developed in the central valley, and consist of blue calcareous clays, brown sandy shales, bands of calcareous sandstone, and conglomerates. The fossils are very abundant and mostly belonging to the Pliocene period.

Some of the calcareous sandstone bands very closely resemble the Kerynia Rock; but the real equivalent of this rock is the yellow calcareous sandstone capping the hills in the neighbourhood of Nicosia and Athienu. At Kerynia, the lower beds do not exist, and the Kerynia Rock rests unconformably on the 'Konnos.' This rock is a yellow calcareous sandstone, or shelly limestone. It is here generally termed a sandstone, because in general appearance and formation it more resembles sandstone than limestone. It is from the Kerynia Rock that the building stone used in the island is chiefly obtained.

Deposits of calcareous tuff and traventine occur on the flanks of the mountains. In most cases the character of these beds is easily recognisable, but in some instances they scarcely differ from compact limestone.

Old river-gravels cover a considerable area on the south side of the central valley.

When cemented by the infiltration of CaO_3 they are scarcely distinguishable from some of the older conglomerates.

Raised beaches exist, between La Scala and Voroklini, between Famagousta and Varoschia, and on the northern coast near the mouth of the river Panagra. The shells found are, for the most part, species now living in the Mediterranean.

Parts of the surface of the island are covered with a hard encrustation, known by the name of 'kavara.' The formation of this surface rock is caused by the re-deposition of calcareous matter amongst the gravels, loams, decomposed shales, and other rocks forming the surface soils.

Blown sands occur on the raised beaches near Famagousta, on the northern coast, and in the valley of the river Angelos, between Myrtu and Morphu.

The alluvial deposits consist of sand, gravel, and sandy loams and clays, forming rich and fertile land.

From the character of the rocks now described there is no difficulty in assigning the formation of the Nicosia Beds to Pliocene times. The Miocene age of the Idalian Beds is somewhat more doubtful. Below this all is uncertainty. Hitherto neither the 'Konnos,' nor the Mount Hilarion Limestone, has yielded any fossils. What length of time elapsed between the formation of the compact limestone and the 'Konnos,' or between the 'Konnos' and the Kerynia Rock, it is impossible to estimate. Failing palæontological evidence it is impossible to say what formations may be wanting. Lithological characteristics are not implicitly to be depended on, but it is better to give them due consideration than to assume a regular succession of formations, as Gaudry has done. Starting from the well-defined horizon of the Nicosia Beds, he classifies the Idalian Beds as Miocene, the 'Konnos' as Eocene, and the Mount Hilarion Limestone as Cretaceous, thus establishing a regular succession in the series. The 'Konnos' has much lithological resemblance to the Vienna Sandstone, and the compact limestone to many of the Jurassic limestones. This classification has been adopted by Unger and Kotschy, and has at least some evidence in its favour.

The trachyte on which the Idalian Beds rest, on the flanks of the Troödos, appears to be the same rock as occurs at Mavro Vouni, and as appears at different places in the Kerynia range. It is a red, grey, and greenish vesicular and amygdaloidal trap, traversed by an immense number of joints, filled with calcareous matter, so that the surface of the rock has the appearance of the irregular pavement seen in the streets of ancient Roman towns. The lower portion of this trachyte contains beds, veins, or dykes of traps, which stand up above the weathered surface like walls. Below this are found regularly bedded lavas, which surround the serpentines constituting the centre of the Troödos mountain-chain.

These volcanic rocks, for the most part, have been formed prior to the formation of any of the stratified rocks. The invariable occurrence of the amorphous trachyte at so many places on both sides of the central valley, seems to point to its extension under the Tertiary rocks occupying the central portion of the island. There is some metamorphism observable among the stratified rocks near their junction with the trap. This is due to some later action than the formation of the trachyte, as the Idalian Beds rest on its denuded surface, and outliers of these beds exist at many different places on the flanks of the southern range. The metamorphism is seen in the brown laminated shales with dark chert, in the pink-tinted beds, and in the schistose limestone, and probably dates from the great elevation of the land which took place at the end of Tertiary times. At this period the land was raised, at least, from 1,800 to 2,000 feet.

Since then an elevation of less extent has occurred. This last upheaval is of comparatively recent date, and not more than 15 or 20 feet in vertical height.

---

12. *Observations on the two types of Cambrian beds of the British Isles (the Caledonian and Hiberno-Cambrian), and the conditions under which they were respectively deposited. By* Professor EDWARD HULL, *LL.D., F.R.S.*

In this paper the author pointed out the distinctions in mineral character between the Cambrian beds of the North-West Highlands of Scotland, and their assumed representatives in the East of Ireland, Wales, and Shropshire. In the former case, which included the beds belonging to the 'Caledonian type,' the formation consists of red or purple sandstones and conglomerates; in the latter, which included the beds belonging to the 'Hiberno-Cambrian type,' the formation consists of hard green and purple grits and slates, contrasting strongly with the former in structure and appearance.

These differences, the author considered, were due to deposition in distinct basins, lying on either side of an archæan ridge of crystalline rocks, which ranged probably from Scandinavia through the central Highlands of Scotland, and included the North and West of Ireland, with the counties of Donegal, Derry, Mayo, Sligo, and Galway, in all of which the Cambrian beds were absent, so that the Lower Silurian repose directly and unconformably on the crystalline rocks of Laurentian age, as shown in a previous paper.

As additional evidence of the existence of this old ridge, the author showed that when the Lower Silurian beds were in course of formation, the archæan floor along the West of Scotland must have sloped upwards towards the east, but he agreed with Professor Ramsay, that the crystalline rocks of the Outer Hebrides formed the western limit of the Cambrian area of deposition, and that the basin was in the form of an inland lake.

On the other hand, looking at the fossil evidence both of the Irish and Welsh Cambrian beds, he was of opinion that the beds of this basin were in the main, if not altogether, of marine origin, and that the basin itself had a greatly wider range eastward and southward, the old archæan ridge of the British Isles forming but a small portion of the original margin.

The Cambrian beds above referred to consist of the Llanberis, Harlech, and Longmynd series, with their representatives at St. David's, in which Dr. Hicks has discovered a primæval marine fauna.

---

13. *On the Lower Cambrian of Anglesea.* *By* Professor T. McK. Hughes, *M.A.*, *F.G.S.*

In this paper the author gives the results of further examination of the basement beds of the Cambrian, which he has now traced all along the N.W. flank of the Archæan axis of Llanfaelog.

He found it resting in some places on gneissic rocks, varying from massive granitoid to fine foliated schistose gneiss, and in other places the Cambrian was seen lying on greenish or blue schist, probably, he thought, the equivalent of part of the Bangor beds.

But whatever it had below it there was such a similarity in the character of the basement-beds that he had no difficulty in following it and mapping it. The sequence which he found almost invariable was in ascending order.

(A) Quartz conglomerate passing up into
(B) Grit, which in turn became finer and passed into
(C) Sandstones, weathering brown, which got split up in their upper part by thin slabby shales (C2). These were succeeded by
(D) Black shales with subordinate beds of black breccia (D2), and occasionally sandstones in the lower part.

The conglomerate at the base was sometimes very thin, being only a foot or so in one section mentioned. In this case the base of the Cambrian was a kind of gneiss-arkose, which was seen resting on true gneiss, and in the grit and conglomerate, within twenty feet of the base, he had found abundant specimens of Orthis Carausii. In another section, a few miles off, in the grits within about fifty feet of the base, he had found annelids and fucoids—while in a third case, close by, the basement conglomerate was split into two parts by a bed of black shale some twenty feet thick.

The brown sandstones and the black breccias had also yielded O. Carausii and a few other fossils.

The petrological characters of the basement-beds were generally very constant, though small variations accompanied the differences in the underlying rocks. For instance, where they rested on the chloritic schists, which were seen under the microscope to consist of a fine felspathic mud, not only did fragments of this rock occur in the conglomerate, but much of its material was found finely comminuted in the matrix of the overlying series. Occasionally some way up in the basement-beds, bands of large felsite pebbles were found, showing the drifting of the shingle now and then from the more distant rocks of the felsitic series or Dinorwig Beds. On the whole he considered that it was quite clear that the quartz-jasper conglomerates and the felsite conglomerates belonged to the same series, and formed part of the basement-beds of the Cambrian.

---

14. *On the Gnarled Series of Amlwch and Holyhead in Anglesea.* *By* Professor T. McK. Hughes, *M.A.*, *F.G.S.*

The author offers the results of his inquiries into the age of certain schists which form the main mass of the rocks of Northern and Western Anglesea, leaving for the present the consideration of two masses of somewhat similar rock which occur S. of the Llanfaelog gneissic axis in the central and south-eastern part of the island.

The two views hitherto current as to their position were:

1. The metamorphic theory of Professor Ramsay, who referred them to altered Cambrian and Silurian.

2. The view of Dr. Hicks and others, who considered them to be the upper part of the Archæan rocks.

The author offers a third explanation, which he calls at present only a good working hypothesis, but for which he thinks that the evidence he has already collected makes out a strong probability.

He uses the term metamorphic for those rocks only in which there has been a complete re-arrangement of the constituent minerals, and excludes therefore all merely consolidated matter, though crystallised as limestones, compacted as quartzite or veined, or filled with replacing minerals, as chert, or crumpled, which he considers merely an accident which may happen to an ordinary sedimentary or to a metamorphic rock, and the cause and mode of occurrence of which he explains.

The difficulty with regard to the Amlwch and Holyhead beds arose from considering them metamorphic, an impression derived from their gnarled and contorted appearance. He describes the sequence commonly found among the lower beds of the series, from the constancy of which he infers that no large mass of them is faulted out of sight in the Amlwch district. He points out the agreement of these sections with some of those in the Holyhead area. He gives a number of sections along the border country between them and the black slates, which seem to indicate a passage up from the slates into satiny beds, which when consisting of rapid alternations of soft material, and hard unyielding bands, become contorted and gnarled.

If these sections cannot be explained away, the felspathic gnarled rocks must be either the marine equivalents of the Bala volcanic series, or the result of a later (probably Silurian) denudation of those beds. As Lower May Hill (=Birkhill) fossils only occur in the slates immediately south of the area in question, the latter supposition is the only one tenable in the present state of the evidence.

---

15. *The Subject-matter of Geology, and its Classification.* *By* Professor W. J. Sollas, *M.A.*, *F.G.S.*

The object of this paper is to remove certain prevailing misconceptions on the aim and scope of Geology. The accepted definition of Geology as 'the history of the earth's crust and the fossils it contains' is shown to be both too wide and too narrow; too wide since it includes Palæontology, which so far as it is a study of forms of life belongs to Biology, and too narrow since the science of the whole earth necessarily embraces much more than a study of its crust. Geology is one of a group of three concrete sciences, which are Astronomy, Geology, and Biology. The scope of Geology, as the science of the earth, is so wide that a fresh classification of its subject-matter is required. In Morphological Geology, Geography, Petrology, Lithology, Mineralogy, correspond to Anatomy and Histology in Biology, minerals, rocks, and rock masses constituting the earth's crust as cells, tissues, organs constitute living organisms; while Palæogeography is a study of successive morphological states corresponding to Embryology or Development.

Physiological Geology considers the movements of the earth as a whole, and of all activities produced upon it by extrinsic and intrinsic forces, acting singly or in combination; it rightly includes Meteorology and Hydrology, as well as the physiology of the earth's crust. Distributional Geology seeks to determine the distribution of the earth in time and space, and Ætiological Geology includes the study of what is known as Cosmogony.

---

16. *On the Exploration of a Fissure in the Mountain Limestone at Raygill.* *By* JAMES W. DAVIS, *F.G.S., F.L.S.*

About eight years ago attention was called, by R. H. Tiddeman, M.A., of H.M. Geol. Survey, to a fissure in the limestone quarry at Raygill, in Lothersdale, about five miles from Skipton. It originally opened to the surface, and during repeated operations in quarrying was found to extend almost vertically into the rock, trending slightly in a southerly direction. The mouth of the fissure was closed up by a thickness of blue clay with limestone boulders several yards in depth, which appears to have been similar to other masses of blue clay in the immediate neighbourhood—the result of glacial action. Underlying this there were successive deposits of yellow clay; a considerable thickness of finely laminated clay, of a bluish colour, fine and unctuous to the touch; and alternating layers of sand and sandy clay, with numerous angular and subangular masses of limestone and grit-rock.

Neither of the beds enumerated contained fossils, but still lower a brown sandy clay was found, with numerous well-rounded, water-worn pebbles of limestone and sandstone, apparently all derived from the rocks in the neighbourhood. Intermixed with the clays and stones of this bed were numerous bones and teeth. The sand and clays surrounding the bones were cemented firmly together, forming a hard enveloping matrix, and as the bones when found are soft and friable, it is with difficulty that they can be extracted except in fragments. In 1879, the quarrying operations had exposed the latter stratum, and the presence of numerous bones led the Council of the Yorkshire Geological Society to decide that a scientific investigation of the fissure should be attempted, with the result that a special fund was obtained, and with the ready permission and co-operation of Mr. Spencer, the proprietor of the quarry, operations were carried on during the summer of 1880. The course of the fissure was exposed to a further depth of nearly 50 feet, in that distance extending 19 feet into the rock from the face of the quarry. It was then found that the fissure extends nearly horizontally, in an easterly direction, which can be followed for about 40 feet, whilst a second branch extends in a southerly direction and appears to fall rapidly. The whole surface of the fissure is abraded and smoothened as by running water, and the limestone in its vicinity is extensively honeycombed. The excavation has resulted in the discovery of numerous bones of *Elephas*, including fragments of a tusk 7 inches in diameter, and many molar teeth. Teeth and tusks of *Hippopotamus*; teeth of *Rhinoceros leptorhinus*, and two imperfect examples of the horn of a roebuck, *C. Capreolus*. The teeth of *hyena* are numerous, and one or two examples of those of the *Lion* have been found. A single molar tooth of the *bear* has also been found, and there are some smaller bones which have not been identified.

The mouth of the fissure is near the summit of an anticlinal which brings the limestone to the surface at Raygill. On either side are hills, composed principally of shale, surmounted by gritstone, dipping north and south; towards the west also the ground rises, and a fault brings down the gritstone into juxtaposition with the limestone, so that on three sides the mouth of the fissure is surrounded by moorlands of gritstone. It appears probable that a stream ran from this surface of gritstone and emptied itself into the fissure, from which were deposited the sandy and clayey matters which gradually filled it. The animals whose bones are found in the fissure no doubt frequented the district through which the stream ran, and their skeleton remains were washed into the fissure along with the rounded stones and boulders found associated with them. It may perhaps be inferred, from the fact that the fine blue clay is superimposed on all the other beds, that the organic remains found in the fissure are preglacial or interglacial in age, because the district drained by the stream is entirely composed of grit-rocks; and it is only by the agency of glaciers that the limestone forming the blue clays could be conveyed to so high elevations, prior to its re-deposition in the fissure.

---

17. *On the Zoological position of the genus* Petalorhynchus, *Ag., a Fossil Fish from the Mountain Limestone. By* James W. Davis, *F.G.S., F.L.S.*

The two species of *Petalodus*, viz. *psittacinus*, Ag., and *sagittatus*, Ag., are included in the new genus *Petalorhynchus*, as well as that of *Chomatodus truncatus*, Ag. The characters and arrangement of the teeth, discovered since Professor Agassiz instituted these genera, show that they extended in circular rows of probably seven teeth in each upper and lower jaw. In front of these are four or five vertical rows of disused teeth, which appear to serve the purpose of strengthening and supporting the row in use. In many respects they are similar to the genus *Janassa*, Munster, and with it appear to occupy an intermediate position between the genus *Myliobates* and Cestraciontes, approaching nearer to the characters possessed by the rays than the sharks.

---

18. *On* Diodontopsodus, *Davis, a new genus of Fossil Fishes from the Mountain Limestone, at Richmond, in Yorkshire. By* James W. Davis, *F.G.S., F.L.S.*

A number of teeth have been found in the Yorkshire Limestone, which were ascribed by Professor Agassiz to the genus Petalorhynchus. They differ most materially from that genus. In Diodontopsodus the teeth are extremely like the single teeth of the existing fish, Diodon, in which the two rami of each jaw have coalesced to form a single, bony, enamel-tipped inciso-palatal tooth, whilst in Petalorhynchus the teeth are strong, with a long and thick base, the crown being thin, sharp, and spatulate; the teeth of Diodontopsodus have no basal prolongation, are hollow, and appear to have been attached to a cartilaginous jaw.

WEDNESDAY, SEPTEMBER 7.

The following Reports and Papers were read:—

1. *Report on the Earthquake Phenomena of Japan.*—See Reports, p. 200.

---

2. *A Contribution to Seismology.*[1] *By* John Milne, *F.G.S., and* Thomas Gray, *B.Sc., F.R.S.E.*

This paper is divided into two parts. The first part treats for the most part of mechanical contrivances designed by the authors for the purpose of earthquake investigation. It was pointed out that many of the instruments formerly in use for such purposes gave very indefinite results, and hence were at the most only entitled to the name seismoscopes.

[1] The substance of this paper has been published under the title 'Earthquake Observations and Experiments in Japan,' in the *Philosophical Magazine* for November, 1881.

Several very sensitive forms of seismoscopes were described, such as the 'tremor indicator' and 'circuit-closer seismoscope,' full descriptions of which will shortly appear in the 'Transactions' of the Seismological Society of Japan for 1881.

A large number of different contrivances for the purpose of measuring accurately the amplitude, period, and direction of motion at any instant during an earthquake-shock is referred to. For descriptions of such contrivances reference may be made to the 'Philosophical Magazine' for September 1881, and to the 'Transactions' of the Asiatic Society of Japan for 1880-81, in one or other of which accounts of most of them will be found.

The second part of the paper treats of earthquake motion generally; the different modes of determining theoretically and practically the rates of propagation of an earthquake wave; the effect of continued action on the area affected; the different modes of determining the origin; the effects of earthquakes on buildings of different form and in different situations; the proper mode of determining the intensity of an earthquake-shock; the explanation of the rotation of bodies by earthquakes, &c.

It is pointed out that earthquake-motion is generally of a very irregular character, that it usually begins gradually, reaches a maximum somewhat suddenly, and afterwards passes through several minima and maxima. The period of vibration of a great number of earthquakes observed by the authors, varied between one-half and one-fifth of a second, while the total time of disturbance varied from one-half to three minutes. Reasons are given for believing that earthquakes which last for a long time are propagated farther than those which last for a short time, even when the intensity of the latter is the greater.

With regard to the determination of the origin of shock, the great value of accurate time-observations is pointed out, and a sketch of several different modes of making such observations is given.

The effect of an earthquake on a building appears to depend mostly on the nature of its foundation (the best probably being a somewhat broad concrete foundation resting on a soft bottom); the agreement or non-agreement of the vibrational period of the different parts; and the situation of the building, it being unsafe to build near the edge of a plateau, or near the junction of a plain with a steep hill or cliff.

It is pointed out that in estimating the intensity of an earthquake-shock the maximum velocity of a particle on the earth's surface during the shock should be taken, and that the intensity is best measured in terms of the square of this velocity. In other words the intensity is proportional to amplitude of movement, and inversely proportional to square of period. The usual explanation of the rotation of bodies during a shock, namely, that of vortex movement, is referred to, and it is pointed out that this is not likely to produce the rotation in question; but, on the other hand, that if a direct backward and forward movement be given in proper direction a rotation will take place. For simplicity, the body may be supposed to have a rectangular base. If the direction of the shock is at right angles to one of the sides or along one of the diagonals, no rotation will take place; but if it be inclined to either of these directions, it may be resolved into two components, one of which tilts the body up in one corner while the other rotates it round that corner as a pivot. The application of this to the determination of direction is referred to.

---

3. *Final Report on the Thermal Conductivities of certain Rocks, showing especially the Geological Aspects of the Investigation.*—See Reports, p. 126.

---

4. *On an International Scale of Colours for Geological Maps. By* W. Topley, *Geological Survey of England and Wales.*

The author described the objects of the International Geological Congress, appointed to meet at Bologna in September 1881. Three main subjects to be discussed were :—*a.* Colours and signs for Geological Maps; *b.* Nomenclature of rocks and formations; *c.* Nomenclature of species. This paper was concerned only with the first of these questions, and especially with the resolutions passed by the English Map-Committee, of which Prof. Ramsay is President, and the author Secretary.

At present, all countries, and many map-makers in each country, have different systems of colouring maps, and it is necessary carefully to study the Index, or scale of colours used, before the maps can be at all understood. The Congress proposes to frame a scheme of colouring which can be used, and readily understood, by all nations. It may not be possible, at least for some time to come, to apply this scheme to national surveys in progress; but it is to be hoped that the scheme to be adopted will be used in new maps. One important point which the Congress proposes is the preparation and publication of a general map or atlas of Europe, compiled (under the authority of the Congress) from various national surveys, and the work of independent observers.

The scheme of colouring proposed by the English Committee is one based on the order of colours in the solar spectrum, violet denoting the older rocks. Bright reds are reserved for igneous rocks. Metamorphic rocks will be shown by dark bands of colour over the colour denoting the age; to these will be added bands of colour showing the period at which metamorphism has taken place, when such fact is clearly established; thus, Silurian rocks metamorphosed in Cretaceous times would be shown by violet, striped with alternate lines of dark violet and green. The sub-divisions of a formation will be shown by shades of the body colour, the darkest shade denoting the oldest sub-division. The letter denoting the formation will be the capital initial letter of the name of the formation. With very small accommodations one system of lettering can be made to apply to all countries.

It has been found impossible to adhere strictly to the order of colours of the spectrum, and an interpolation has been made of browns and greys for the series of beds between the Silurian and the Lias.

Examples of maps and tables of strata were exhibited, coloured according to the plan adopted. Also a series of indexes of colours issued at various dates by the Geological Survey, commencing with one, in MS., by Sir H. De la Beche, the founder and first Director-General of the Survey; this was made in 1832. The author also drew attention to a proposal, made by Mr. J. W. Salter, before this Association in 1847,[1] and again in a map exhibited at the International Exhibition in London, in 1862, to colour Geological maps in the order of colours of the solar spectrum. The plan recommended by the English committee differs considerably in detail from that of Mr. Salter.

---

5. *On the Glacial Geology of Central Wales. By* WALTER KEEPING, *M.A., F.G.S., Keeper of the York Museum.*

Cardiganshire and the neighbouring counties of Central Wales form a mountainous tract of country, consisting of rounded, grass-covered hills, often with flattened peaty summits. Geologically, the district consists of monotonous repetitions of grit, and greywacke, shales and slates.

The most important physical features are the two great planes of marine denudation which limit the tops of the hills at heights of 500 ft. sloping up to 700 ft., and 1,100 to 1,500 ft. respectively. The drift-deposits range over both these hill-groups, stretching up to within 100 ft. of the highest points.

All the drifts in the central part of the district are of local origin, the materials being derived from within the limits of the present drainage-areas. Glaciated rock-surfaces are left in perfect preservation, excellent examples being seen in the *roches moutonnées* of the Llyfnant valley, and many other places. The stony clay or Till consists generally of a matrix of amorphous, stiff blue clay, crowded with small angular grains and shaly fragments. This paste is thickly studded with

[1] *Report of the British Association* for 1847. Sections, 69.

rocks of all sizes, from mere fragments to large masses several tons in weight. Most of these stones are subangular, and well striated; a few are rounded, and others are unworn and angular. In the cliffs four miles south of Aberystwith, this formation occupies an old river-bed in a former valley, whose western hill-boundary has been destroyed by marine denudation; also the rock here has been eaten away by streamlet and pluvial denudation into fantastic gorges and columns, some of the latter being true earth-pillars, like those of Botzen in the Tyrol. Moraines are of common occurrence, but they consist of more clayey material than usual, which results from the argillaceous character of the surrounding rocks. In some cases they occur at the foot of lakes.

Erratic blocks are abundant, occurring at heights above 1,000 ft. They are often found along the sides of valleys, where they appear to have been stranded after being launched off from the sides of the subsiding glaciers. All are local rocks, and it is only in the extreme north and south that boulders from beyond the present drainage-areas occur. In the Llyfnant valley, S.W. of Machynlleth, huge boulders of felsite from the Cader Idris and Aran range of mountains are found, they having been carried over the pass by the North Wales ice, which overflowed beyond the Dyfi valley. In the south the Teifi valley at Cardigan was invaded by a large glacier, whose birthplace was in the mountains of Caermarthenshire. Lakes and lakelets are abundant, especially on the higher plateaux. They are all rock-basins, mostly shallow, and of irregular outline. One of them (Llyn Llygad Rheidol) was apparently ice-formed; the rest cannot be. These evidences show that Central Wales was covered with snow and ice during the Glacial period; but all the glaciers of which we have any traces were of strictly local character, each confined to its own drainage-area in the present valley system. There is no evidence of any great *mer de glace*, or of any marine submergence in recent geological times.

---

6. *On some points in the Morphology of the Rhabdophora.* *By* John Hopkinson, *F.L.S.*, *F.G.S.*

Professor McCoy ('Brit. Pal. Foss.' 1854) speaks of transverse diaphragms at the base of the calycles (hydrothecæ) of certain graptolites, dividing the calycles from the common canal or perisarc. No further allusion appears to have been made to the presence of any diaphragms or septa until, in 1868, the author mentioned ('Journ. Quek. Micr. Club,' vol. i.) having observed 'an impressed line between the hydrothecæ and the periderm' (perisarc), which was compared with that 'at the base of the hydrothecæ in the Sertulariadæ.'

More recently Professor Allman ('Mon. Tubularian Hydroids,' 1872), not admitting the presence of any septum or constriction, has compared the calycles of the Rhabdophora to the nematophores of the Plumularidæ.

A few days ago the author examined an extensive collection of graptolites made by Mr. W. Kinsey Dover, of Keswick, from the Skiddaw Slates, amongst which are a few specimens showing internal structure, most clearly defined in *Didymograptus nitidus* and *patulus*, and *Tetragraptus serra*. In several specimens of these species (exhibited) the thecæ are seen to be separated from the perisarc by a distinctly-marked septum which seems usually to form a right angle with the thecæ. The perisarc is, moreover, in specimens of all the three species, seen to be jointed, or crossed by transverse septa, there being one septum to each theca. The appearance is therefore that of a common perisarc divided into chambers, from each of which a single isolated hydrotheca is produced.

These appearances are not confined to the graptolites of the Skiddaw Slates, having been noticed by the author in well-preserved specimens from the Ludlow rocks, and it is believed to be owing to the imperfect state of preservation in which graptolites usually occur that they are not more frequently seen. The true interpretation of the appearances presented is believed to be that the septa which seem to completely cut off the thecæ from the perisarc, and the sections of the perisarc from each other, only partially do so, as in the recent Thecaphora; and the author concluded that these specimens show that the calycles of the graptolites are true hydrothecæ, and do not in any way invalidate the conclusion arrived at from previous investigations into the morphology of the Rhabdophora, that they are the Palæozoic representatives of the recent Hydroida.

---

7. *On some Ores and Minerals from Laurium, Greece.* *By* H. STOPES, *F.G.S.*

The metals of Greece are numerous and pay to work. The quantity of gold is small, but at Doliana a bed of pyrites yields from 14 to 18 dwts. per ton. Most abundant metals are lead and zinc, with a large quantity of silver mixed, and some copper. Several mining companies now working successfully; at present chiefly washing and re-smelting the scoriæ left by ancient miners. Formerly mining in Attica was very largely carried on over 50,000 acres of ground worked, and upwards of 2,000 galleries and shafts still remain, some as perfect as if left but yesterday. The shafts vary from 20 to 140 yards deep. Excavations commence from narrow galleries to wide chambers, 30 feet high and of great length. Vast numbers must have been worked, as of the scoriæ left over 2,000,000 tons are officially reported to exist, and many vast heaps were not measured. Taking the quantity stated, and allowing nothing for other loss, upwards of 2,000,000 tons of lead, and 8,250 tons of silver, are thus known to have been extracted, chiefly by Athenians. Existing ores contain 65% of lead. The scoriæ still retain 10% and pay to work. Silver is invariably mixed. The argentiferous lead occurs in veins and pockets in granite, mica-schists, trachyte, limestones, &c. (sometimes in great masses). Zinc occurs chiefly in veins in limestone rocks, close-grained marble, sometimes in pockets, frequently mixed with other metals. Although copper and nickel are present in paying quantities, at present they are not worked. Attica is a great field for mining industry, and Greece will in a few years add largely to her wealth from her minerals. In addition to those mentioned, coal (lignite), marble, sulphur, emery, arsenic, manganese, iron, barytes, and many other minerals of excellent quality and in great abundance, are already being worked.

---

8. *Notes on the Cheshire Salt-field.* *By* C. E. DE RANCE, *F.G.S., Assoc. Inst. C.E.*

The author regards the brine of this area as underground water, travelling through porous rock, which, coming in contact with rock-salt, becomes brine, which rises at pressure in natural springs, occurring along joints and other lines of weakness, and at the points where the 'inverted syphon' has been reached by shafts, in which the brine rises in the manner that water rises in artesian wells. The total quantity of brine produced, whether wholly issuing as springs or partially intercepted by artificial works, is limited by the area of percolation, alone occurring along the line of the original outcrop of the rock-salt. The effect of rainfall, though not immediately raising the level to which the brine will rise, is invariably felt.

---

9. *On some sections in the Lower Palæozoic Rocks of the Craven District.* *By* J. E. MARR, *B.A., F.G.S.*

The sections are described by Professor Hughes ('G. M.' vol. iv.), but the age of the beds is not definitely determined. The beds are as follows:—

Austwick Beck, conglomerate resting unconformably on Bala beds, interstratified with black shale, passing up into deposit of similar shales. These black shales, surmounted by flaggy bed three to four inches thick, with *Phacops elegans*, Boeck & Sars. Above this are pale green shales, and then flags with *Monograptus priodon* and *M. vomerinus.* Similar section at Crumwark Beck Head.

In Lake district, bed, with Phacops elegans, lies between graptolitic mudstones and pale shales, and lithological characters of beds precisely similar to those of beds near Austwick. Phacops elegans, hitherto unrecorded in England, is characteristic of May Hill species, and thus forms useful fossil for determining horizon.

Section D.—BIOLOGY.

President of the Section—Richard Owen, C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.Z.S.

DEPARTMENT OF ZOOLOGY AND BOTANY.

THURSDAY, SEPTEMBER 1.

The President delivered the following Address:—

The recent construction of the edifice of the 'British Museum (Natural History), Cromwell Road,'[1] and the transference thereto of three of the Departments, the systematic arrangement of which in their respective galleries approaches closely to completion, have left me little leisure in the present year for other scientific work. The expression, moreover, in divers forms and degrees, of the satisfaction and instruction such partial exhibition of the national treasures of natural history has afforded to all classes of visitors since the galleries were open to the public, in April last, encourages me to believe that a few words on this great additional instrument in advancing Biological Science may not be unacceptable to the Section of the British Association which I have now the honour to address.

It is true that when we last met at Swansea, my accomplished colleague, Dr. Albert Günther, F.R.S., selected a general description of the building as the subject of his address to Section D.

I was unwilling then, in consideration of the time of the Section already given to the matter, to respond to appeals of some of our fellow-members for information as to how, and through whom, the new Museum came to be, and to be where it is; but now, honoured by my present position, I venture to hope that a brief outline of its genetic history, which I have been preparing for publication in a fuller form, may be condoned.

In the actual phase of Biology, its cultivators, especially the younger generation, do not rest upon the determination and description, however minute and exhaustive, of the acquisitions so rapidly accumulating of objects or species 'new to science,' but devote themselves also, and more especially, to the investigation of their developmental phenomena.

It has therefore seemed to me that it would not be inappropriate, as being germane to the present phase of research, to submit to the Section a few words on the genesis of this new national edifice, generously provided by the State for the promotion of our sciences of natural history.

On the demise, in 1856, of Sir Henry Ellis, K.T., then Principal Librarian of the British Museum, the Government, made aware of the growth of the departments of natural history, more especially of geology and palæontology, since the foundation of the Museum in 1753, when the collections of printed books and manuscripts predominated, determined that, together with a principal librarian, there should be associated a new official having special charge of the collections of natural history, but under similar subordinate relations to the Trustees. To this official was assigned the title of 'Superintendent of the Departments of Natural History,' and I had the honour to be selected for this office.[2]

[1] The official designation assigned by the Trustees to the building and its contents.
[2] The date of my appointment is May 26, 1856.

Almost my first work was to ascertain the extent of my charges, and I confess that I was unprepared to find that the galleries assigned for the arrangement and public exhibition of the several natural history series in the British Museum were so inadequate to these ends as to necessitate the storage of many unexhibited, and in great proportion rare and valuable specimens. This condition affected principally the collection of fossil remains, but in not much less degree that of the recent natural history.

One of my colleagues, Mr. Charles König, then Keeper of the Department of Mineralogy, and most eminent in that science, applied the gallery assigned thereto principally to the rare and beautiful specimens of his favourite subject. When the newer science of palæontology entered upon its rapid growth, and, on the demise of Mr. König, led to the formation of a distinct Department of Geology, the proportion of the British Museum set apart for natural history would not afford for the exhibition of the fossils and rock specimens more or other space than might be gained from or intercalated among the mineral cabinets in one and the same gallery, viz. that which had been originally assigned to Mr. König.

The store-vaults in the basement of the Museum became accordingly invaded by the rapidly-accumulating unexhibited geological specimens, as those receptacles had been, and continued to be, needed for the storage of such specimens, and especially the osteological ones, of the Department of Zoology.

In 1854, Dr. John Ed. Gray, Keeper of the Zoology, reported on the unfitness of the locality of his stored specimens, and prayed for additional accommodation for them.[1] But, on the report of the architect, to whom such appeal was referred, the Trustees 'declined to adopt Dr. Gray's suggestion,' and recommended 'that steps should be taken to obviate the deterioration of the specimens complained of by Dr. Gray in consequence of the damp condition of the vaults in which they are contained.'[2] To renewed appeals by the experienced Keeper, and agreeably with his ideas on the nature and extent of the required additional space for the Zoology, the Trustees recommended:—'An additional gallery to the Eastern Zoological Gallery, and the substitution of skylights for the side windows,' with a view to an additional gallery at an elevation above the floor of the one in use; they also resolved:—'That accommodation be provided for the officers of the Natural History Departments on the roof of the Print-room.'[3]

But the inadequacy for exhibition-purposes of additional space which might be gained by the new gallery, or by the accessory wall-gallery attainable by stairs in the one in use,[4] was so impressed on my convictions, that I determined, in 1857, to submit to the Trustees a statement embodying estimates of space required for exhibition of all and several the Departments of natural history, with the grounds of such estimates, including considerations based upon the ratio of increase during the ten years preceding my appointment, and the conditions likely to affect the proportions of future annual additions.

This purpose, which I deemed a duty, I endeavoured to effect in a 'Report, with a Plan,' submitted on February 10, 1859, which Report, being forwarded by the Trustees to the Treasury, and being deemed worthy of consideration by Parliament, was 'Ordered by the House of Commons to be printed, March 11, 1859,' and can still be obtained at the Office of Parliamentary Papers.[5]

The Report included, as I have stated, estimates of space for the then acquired specimens of the several departments of natural history, together with space for the reception of the additional specimens which might accrue in the course of a

[1] See Parliamentary Paper or Blue Book, folio 1858, entitled:—'Copies of all Communications made by the Officers and Architect of the British Museum to the Trustees, respecting the want of space for exhibiting the Collections in that Institution,' p. 4.

[2] Ibid. p. 5. [3] Ibid. pp. 25, 28.

[4] In his report of December 29, 1856, Dr. Gray states:—'Scarcely half of the zoological collections is exhibited to the public, and their due display would require more than twice the space devoted to them.'—Ibid. p. 21. To any removal of the natural history to another site Dr. Gray was strongly opposed.

[5] Parliamentary Papers, 'Report with Plan,' &c. (126, i.), fol. 1859.

generation, or thirty years. It further recommended that such museum-building, besides giving the requisite accommodation to the several classes of natural history objects, as they had been by authority exhibited and arranged for public instruction and gratification, should also include a hall, or exhibition-space for a distinct department, adapted to convey an elementary knowledge of the subjects of all the divisions of natural history to the large proportion of public visitors not specially conversant with any of those subjects.

I may crave permission to quote from that part of my Report which has received the sanction of the 'Commission on the Advancement of Science' of 1874: 'One of the most popular and instructive features in a public collection of natural history would be an apartment devoted to the specimens selected to show type-characters of the principal groups of organised and crystallised forms. This would constitute an epitome of natural history, and should convey to the eye in the easiest way, an elementary knowledge of the sciences.'[1]

An estimate of the space required for such apartment is given, and it has been obtained in the new Museum of Natural History.

I ventured also on another topic in connection with the more immediate object of my Report. Previous experience at the museum of the Royal College of Surgeons had impressed me with the influence on improved applications of collections and on the ratio of their growth, through Lectures expository of their nature. I felt confident that, with concurrence of authorities, both relations would be exemplified under the actual superintendence at the British Museum. Moreover, such museum of natural history has wider influences over possessors and collectors of rarities and of desiderated specimens than one of restricted kind, as in Lincoln's Inn Fields. I concluded my Report, therefore, by referring to the lecture theatre shown in my plan, and expressed my belief that 'Administrators will consider it due to the public that the gentlemen in charge of the several departments of the National Collection of Natural History should have assigned to them the duty of explaining the principles and economical relations of such departments, in elementary and free lectures, as, *e.g.* on Ethnology, Mammalogy, Ornithology, Herpetology and Ichthyology, Malacology and Conchology, Entomology, Zoophytology, Botany, Geology, Palæontology, Mineralogy.'

After the lapse of twenty years I have lived to see the fulfilment of all the recommendations, save the final one, of my Report of 1859. The lecture-theatre was erased from my plan, and the elementary courses of lectures remain for future fulfilment.

Considering that, in the probable communication of this Report to Parliament, I was addressing the representatives of the greatest commercial and colonising nation in the globe, representatives of an empire exercising the widest range of navigation and supreme in naval power, such nation and empire might well be expected by the rest of the civilised world to offer to students and lovers of natural history the best and noblest museum of the illustrations of that great division of general science.

But for such a museum, a site or superficial space of not less than eight acres was asked for, the proportion of such space to be occupied by the proposed building to be limited and dependent upon architectural arrangement in one, two, or more storeys. But the effect of restricting the site or available superficial space to that, *e.g.* on which the Museum at Bloomsbury now stands, was significantly demonstrative of difficulties to come, and concomitantly indicative of the administrative wisdom which would be manifested by securing, in a rapidly growing metropolis, adequate space for future additions to the building which might be in the first place erected thereupon.

Nevertheless one or two of my intimate and confidential friends dissuaded me from sending in a Report which might be construed or misinterpreted as exemplifying a character prone to inconsiderate and extravagant views, and such as might even lead to disagreeable personal consequences. Moreover the extent of space reported for seemed inevitably to involve change of locality. Two of my colleagues occupied the elegant and commodious residences attached to the British Museum;

[1] Report, *ut supra*, p. 22.

and it was possible that provision for such residences marked in the plan which accompanied my report might not be adopted. Moreover no statement of grounds for adequate space-requirements for the whole of the National Natural History had previously been submitted to authority. The legislative mind had not been prepared for calm and due consideration of the subject. Still I flattered myself that, by whomsoever the details and aims and grounds of my report were known and comprehended, any strong opposition on the part of Parliament could hardly be expected. Nevertheless, an Irish member, seeing a way to a position in 'The House,' which is gained by the grant of a Committee of Inquiry, of which the mover becomes chairman, made my Report and Plan the ground of a motion to that effect, which was carried. The Select Committee, after taking the evidence published in the Blue Book (ordered to be printed August 10, 1860, quarto, pp. 238, with ten plans), reported against the removal of the Natural History Collections from the British Museum. As to the chief reasons alleged for such removal the Report states that with one 'eminent exception the whole of the scientific naturalists examined before your Committee, including the Keepers of all the Departments of Natural History in the British Museum, are of opinion that an exhibition on so large a scale tends alike to the needless bewilderment and fatigue of the public, and the impediment of the studies of the scientific visitor . . . . Your Committee, therefore, recommend the adoption of the more limited kind of exhibition advocated by the other witnesses, in preference to the more extended method recommended by Professor Owen.'

Lest, however, the House might attach undue weight to the exceptional testimony, the chairman of the Committee deemed it his duty, in bringing up the Report, to warn the House of the character of such testimony, and his speech left, as I was told, a very unfavourable impression as regards myself. I was chiefly concerned to know what might be put upon record in 'Hansard.' In that valuable work Hon. Members revise their reported utterances before the sheets go to press. I was somewhat relieved to find Mr. Gregory regretting that 'a man whose name stood so high should connect himself with so foolish, crazy, and extravagant a scheme, and should persevere in it after the folly had been pointed out by most unexceptionable witnesses.

'They had on one side, and standing alone, Professor Owen and his ten-acre scheme, and on the other side all the other scientific gentlemen, who were perfectly unanimous in condemning the plan of Professor Owen as being utterly useless and bewildering.

'Among these gentlemen were Professor Huxley, Professor Maskelyne, Mr. Waterhouse, Dr. Gray, Sir Roderick Murchison, Mr. Thomas Bell, P.G.S., Dr. Sclater, Sec. Z.S., Mr. Gould, and Sir Benjamin Brodie. To give the House some idea of that gigantic plan, he might mention that a part of it consisted of galleries 850 feet in length for the exhibition of whales. The scientific men examined on the subject, one and all, disapproved of that plan *in toto*; and they advocated what was technically called a "typical mode of exhibition."'[1]

In point of fact that Supplementary Exhibition Room which was planned and recommended for the purpose I have already cited, was urged as the sole reasonably required National Museum of Natural History, for which the nation ought to be called upon to provide space and funds, a conclusion subsequently adopted and unanimously recommended by the Royal Commission on Science.[2]

Although grief was natural and considerable at this result, not without mortification at the reception by Parliament of the Report and Plan submitted thereto, I now feel grateful that the sole responsibility of their author is attested in the pages of a Work[3] which will last as long as, and may possibly outlast, the great legislative organisation whose debates and determinations are therein authoritatively recorded.

I was not, however, cast down, nor did I lose either heart or hope; I was confident in the validity of the grounds of my appeal, and foresaw in the inevitable

[1] *Hansard.* 'Debate of July 22, 1861,' pp. 1861, 1918.
[2] Fourth Report, p. 4.
[3] *Hansard*, *ut supra.*

accumulations year by year, the evidence which would attest its soundness and make plain the emergency of the proposed remedy.

Moreover, there was one who, though not a naturalist, had devoted more time, pains, and thought to the subject than had been bestowed by any of those—whether naturalist or administrator—who testified adversely thereon. The Right Hon. William Ewart Gladstone, an elected trustee of the British Museum, took nothing on trust; he explored with me, in 1861, every vault and dark recess in the Museum which had been, or could be, allotted to the non-exhibited specimens of the natural history, those, viz., which it was my aim to utilize and bring to light. He gave the same attention to the series selected for exhibition in the public galleries, and appreciated the inadequacy of the arrangements to that end. He listened to my statements of facts, to the grounds of provision of annual ratios of increase, to the reasons for providing space therefor, to my views of the aims of such exhibitions, and to the proposed extended applications and elucidations of the collections. Mr. Gladstone tested every averment, and elicited the grounds of every suggestion, with a tact and insight that contrasted strongly with the questionings in Mr. Gregory's committee-room, where too often vague interrogations met with answers to match.

Conformably with Mr. Gladstone's convictions, he as Chancellor of the Exchequer moved, May 12, 1862, for 'Leave to bring in a Bill for removal of portions of the Trustees' Collections in the British Museum.'

On May 19, when the bill was to be read a second time, a new, unexpected, and formidable antagonist arose. Mr. Disraeli early got the attention of the House to a speech, warning hon. members of the 'progressive increase of expenditure on civil estimates,' and laying stress on the fact that the 'estimates of the actual year showed no surplus.'[1] The influence of this advocacy of economy is exemplified in the debate which ensued.[2] For repetitions of the nature and terms of objections to the Report and Plan, as already denounced by Mr. Gregory, Mr. Bernal Osborne, and others, reference may be made to the volume of 'Hansard' cited below. An estimable hon. member, whose words had always and deservedly carried weight with the country party, lent his influence to the same result. Mr. Henley, representative of Oxfordshire, said:—'All the House knew was that a building was to be put up somewhere. He considered this a bad way of doing business, particularly at a time when nobody could be sanguine that the finances of the country were in a flourishing state. Let the stone once be set rolling, and then all gentlemen of science and taste would have a kick at it, and it would be knocked from one to the other, and none of them probably would ever live to see an end of the expense.'[3]

Permit me to give one more example of the baneful influence of the opening speech on our great instrument of scientific progress. Mr. Henry Seymour, Member for Poole, said:—'If a foreigner had been listening to the debates of that evening it must have struck him that it was, to say the least, a rather curious coincidence that a proposal to vote 600,000*l.* for a new collection of birds, beasts, and fishes at South Kensington should have been brought forward on the very evening when the Leader of the Opposition had made a speech denouncing that exorbitant expenditure—a speech, he might add, which was re-echoed by many Liberal members of the House.'[4]

It was however not a 'curious,' but a 'designed coincidence.' Mr. Disraeli, knowing the temper of the House on the subject, and that the estimates for the required Museum of Natural History were to be submitted by Mr. Gladstone, chose the opportunity to initiate the business by an advocacy of economy which left its intended effect upon the House. In vain Lord Palmerston, in reply to the Irish denunciators, proposed as a compromise to 'exclude whales altogether from disporting themselves in Kensington Gardens.'[5] The Government was defeated by a majority of ninety-two, and the erection of a National or British Museum of Natural History was postponed, to all appearance indefinitely, and in reality for ten years.

[1] *Hansard*, 1862, p. 1927. [2] Ibid. [3] Ibid. p. 1932.
[4] Ibid. p. 1918. [5] Ibid. p. 1931.

Nevertheless, neither averments nor arguments in the House on May 19, 1862, nor testimonies in the hostile Committee of 1860, 1861, had shaken my faith in the grounds on which my Report and Plan of 1859 had been based. The facts bearing thereupon, which it was my duty to submit in my 'Annual Reports on the Natural History Departments of the British Museum,' would, I still hoped, have some influence with hon. members of the legislature to whom those Reports are transmitted.

The annual additions of specimens continued to increase in number and in value year by year. I embraced every opportunity to excite the interest of lovers of natural history travelling abroad, and of intelligent settlers in our several colonies, to this end, among the results of which I may cite the reception of the Aye-Aye, the Gorilla, the Dodo, the Notornis, the maximised and elephant-footed species of Dinornis, the representatives of the various orders and genera of extinct Reptilia from the Cape of Good Hope, and the equally rich and numerous evidences of the extinct Marsupialia from Australia, besides such smaller rarities as the animals of the Nautilus and Spirula.

Wherever room could be found in the exhibition galleries at Bloomsbury for these specimens, stuffed or as articulated skeletons, or as detached fossils, they were squeezed in, so to speak, to mutely manifest to all visitors, more especially administrative ones, the state of cram to which we were driven at Bloomsbury.

Another element of my 'Annual Reports' was the deteriorating influence on valuable specimens of the storage vaults, and the danger of such accumulations to the entire Museum and its priceless contents. And here perhaps you may deem some explanation needful of the grounds of the latter consideration addressed to economical granters of the National funds.

The number of specimens preserved in spirits of wine amounted to thousands; any accidental breakage, with conflagration, in the subterraneous localities contiguous with the heating-apparatus of the entire British Museum, would have been as destructive to the building as the gunpowder was meant to be when stored in the vaults beneath King James's Houses of Parliament.

At this crisis the 'Leading Journal,' after the stormy debate of May 19, 1862, made the following appeal to me:—'Let Mr. Owen describe exactly the kind of building that will answer his purpose, that will give space for his whales and light for his humming-birds and butterflies. The House of Commons will hardly, for very shame, give a well-digested scheme so rude a reception as it did on Monday night.'[1]

My answer to this appeal was little more than some amplification, with additional examples, of the several topics embodied in the original Report. The pamphlet 'On the Extent and Aims of a National Museum of Natural History,' with reduced copies of the plans, went through two editions, and no doubt had the effect anticipated by the able Editor.

Another element of reviving hope was the acceptance by Mr. Gregory of the government of a tropical island.

The sagacious Prime Minister accurately gauged the modified feeling—the subsiding animosity—of Parliament on the subject, and submitted (June 15, 1863) a motion 'for leave to purchase five acres for the required Natural History building.' The choice of locality he left to honourable members. Lord Palmerston pointed out that the requisite extent of site could be obtained at Bloomsbury for 50,000*l.* per acre, and that it could be got at South Kensington for 10,000*l.* per acre; and his lordship distinctly stated that the space, in either locality, would be bought for the purpose of a Museum of Natural History. The purchase of the land at South Kensington was accordingly voted by 267 against 135, and thus the Government proposition was carried by a majority of 132. By this vote the decision of Mr. Gregory's Committee was virtually annulled.

In a conversation with which I was favoured by Lord Palmerston, I interpose a warning against restriction of space, and eventually eight acres of ground we obtained, including the site of the Exhibition Building of 1862, opposite Cromw

[1] The *Times*, May 21, in a leader on the Museum Debate.

Gardens, and that extent of space is now secured for actual and prospective requirements of our National Museum of Natural History.

I am loth to trespass further on the time of the Section, but a few words may be expected from me of the leading steps to the acquisition of the present edifice, occupying a portion—about one-third—of that extent of ground.

Mr. Gladstone, adhering to the convictions which led him to submit his financial proposition of May, 1862, honoured me, at the close of that session of Parliament, with an invitation to Hawarden to discuss my plans for the Museum Building; and, after consideration of every detail, he requested that they might be left with him. He placed them, with my written expositions of details, in the hands of Sir Henry A. Hunt, C.B., responsible adviser on buildings, &c., at the Office of Works, with instructions that they should be put into working form, so as to support reliable estimates of cost. I was favoured with interviews with Sir Henry, resulting in the completion of such working plans of a museum, including a central hall, an architectural front of two storeys, and the series of single-storeyed galleries extending at right angles to the front, as shown in my original Plan. I was assured that such plan of building, affording the space I had reported on, would be the basis to be submitted to the professional architect whenever the time might arrive for Parliamentary sanction to the cost of such building.

Here I may remark that experiments which preceded the substitution, in 1835, of the actual Museum of the Hunterian Physiology at the Royal College of Surgeons, for the costly, cumbrous, and ill-lit building, with its three-domed skylights, which preceded it, had led to the conclusion that the light best fitted for a museum was that in which most would be reflected from the objects and least directly strike upon the eye; and this was found to be effected by admittance of the light at the angle between the wall and roof. But this plan of illumination is possible only in galleries of one storey, or the topmost in a many-storeyed edifice. Such system of illumination may be seen in every gallery of the museum described to you last year at Swansea, save those of the storeys of the main body below the skylit one, which necessitate side windows.

I subjoin a copy of the letter from Sir Henry A. Hunt, conveying his conclusions respecting the plan of building discussed with him:—

'4 Parliament Street: September 25, 1862.

'My dear Sir,—I return you the drawings of the proposed Museum of Natural History at South Kensington. In May last I told Mr. Gladstone that the probable cost of covering five acres with suitable buildings would be about 500,000*l.* or 100,000*l.* per acre.

'The plan proposed by you will occupy about four acres, and will cost about 350,000*l.*, or nearly 90,000*l.* per acre.

'Having prepared sketches showing the scheme suggested by you, I have been able to arrive more nearly at the probable cost than I had the means of doing in May last. But, after all, the difference is not great; although the present estimate is a more reliable one than the other. It is right, however, to state that the disposition of the building as proposed by you will give a greater amount of accommodation, and admit of a cheaper mode of construction, than I had calculated upon in May (relatively with the space intended to be covered), and therefore I think your plan far better adapted for the Museum than the plan I took the liberty to suggest to Mr. Gladstone.

'Believe me, &c.,

(Signed) 'HENRY A. HUNT.'

Sir H. A. Hunt had previously formed an estimate of cost for the Chancellor of the Exchequer on inspection of the Report and Plan in the Parliamentary paper of March 1859. The letter to which I refer I regard as an antidote to some previous quotations from adverse members of Parliament.

The working plans of Sir Henry A. Hunt were subsequently submitted for competition, and the designs of the accomplished and lamented Capt. Fowke, R.E., obtained the award in 1864. His untimely death arrested further progress or practical application of the prize designs.

In 1867, Lord Elcho pressed upon the House of Commons, through the Hungerford Bridge Committee, the Thames Embankment as a site for the New Museum of Natural History, but unsuccessfully. The debates thereon, nevertheless, caused some further delay.

In 1871, a vote of 40,000*l.* for beginning the Museum Buildings at South Kensington was carried without discussion. In 1872, a vote of 29,000*l.* for the same building was opposed by Lord Elcho, but was carried by a majority of 40 (85 against 45).

On the demise of Capt. Fowke, Mr. Alfred Waterhouse was selected as architect. He accepted the general plans which had been sanctioned and approved by Sir H. A. Hunt and by Capt. Fowke, and I took the liberty to suggest, as I had previously done to Capt. Fowke, that many objects of natural history might afford subjects for architectural ornament; and at Mr. Waterhouse's request I transmitted numerous figures of such as seemed suitable for that purpose. I shall presently refer to the beautiful and appropriate style of architecture which Mr. Waterhouse selected for this building, but am tempted to premise a brief sketch of what I may call the 'Genealogy of the British Museum,' or what some of my fellow-labourers, agreeably with the actual phase of our science, may prefer to call 'Phylogeny.'

Sir Hans Sloane, M.D., after a lucrative practice of his profession in the then flourishing colony of Jamaica, finally settled at Chelsea, and there accumulated a notable museum of natural history, antiquities, medals, cameos, &c., besides a library of 50,000 volumes, including about 350 portfolios of drawings, 3,500 manuscripts, and a multitude of prints. These specimens were specified in a MS. catalogue of thirty-eight volumes in folio, and eight volumes in quarto. Sir Hans valued this collection at the sum of 80,000*l.*, but at his death, in 1753, it was found that he had directed in his 'will' that the whole should be offered to Parliament for the use of the public on payment of a minor sum, in compensation to his heirs. This offer being submitted to the House of Commons, it was agreed to pay 20,000*l.* for the whole. At the same time the purchase of the Cottonian Library and of the Harleian MSS. was included in the Bill.[1]

The following are the terms of the enactment:—

Act 26 *George II., Cap.* 22 (1753).—*Sections IX. and X.*

"(IX.) And be it enacted by the authority aforesaid, that within the cities of London or Westminster or the suburbs thereof, one general repository shall be erected or provided in such convenient place and in such manner as the trustees hereby appointed, or the major part of them, at a general meeting assembled, shall direct for the reception not only of the said museum or collection of Sir Hans Sloane, but also of the Cottonian Library and of the additions which have been or shall be made thereunto by virtue of the last will and testament of the said Arthur Edwards, and likewise of the said Harleian collection of manuscripts and of such other additions to the Cottonian Library as, with the approbation of the trustees by this Act appointed, or the major part of them, at a general meeting assembled, shall be made thereunto in manner hereinafter mentioned, and of such other collections and libraries as, with the like approbation, shall be admitted into the said general repository, which several collections, additions, and library so received into the said general repository shall remain and be preserved therein for public use to all posterity.

"(X.) Provided always that the said museum or collection of Sir Hans Sloane,

[1] In his letter of February 14, 1753, to his friend Mann, Horace Walpole, then Member for Lynn, writes:—'You will scarce guess how I employ my time, chiefly at present in the guardianship of embryos and cockle-shells. Sir Hans Sloane is dead, and has made me one of the trustees of his museum, which is to be offered for twenty thousand pounds to the King and Parliament, and (in default of acceptance) to the Royal Academies of Petersburg, Berlin, Paris, and Madrid. He valued it at four-score thousand, and so would any one who loves hippopotamuses, sharks with one ear, and spiders as big as geese. The King has excused himself, saying he did not think that there were twenty thousand pounds in the Treasury.'—*Letters to Horace Mann*, 8vo, vol. iv. p. 32.

in all its branches, shall be kept and preserved together in the said general repository whole and entire, and with proper marks of distinction."

The trustees appointed under the Act are of four classes: Royal, Official, Family, and Elected. The first class includes one trustee appointed by the Sovereign; the second class includes the Lord Archbishop of Canterbury, the Lord High Chancellor, the Speaker of the House of Commons, and twenty-two other high officials and presidents of societies. The three first in this class are designated 'Principal Trustees,' and in them is vested the patronage or appointment to every salaried office save one in the British Museum; the exception being the Principal Librarian, who is appointed by the Sovereign. Of the Family Trustees, the Sloane collections are now represented by the Earl of Derby and the Earl of Cadogan, the Cottonian Library by the Rev. Francis Annesley and the Rev. Francis Hanbury Annesley, the Harleian manuscripts by Lord Henry C. G. Gordon-Lennox, M.P., and by the Right Hon. George A. F. Cavendish Bentinck, M.P. Among the Elected Trustees the honoured name of Walpole, associated with the origin of the British Museum, is continued by the Right Hon. Spencer Horatio Walpole, M.P., to whom the requisite Parliamentary business of the Museum is usually confided.

I may call attention to the 'suburbs of London or Westminster' as one of the localities specified in the original Act of Parliament, and such situation was selected for the locality of the Library and the Museum. The Government issued lottery tickets to the amount of 300,000*l*., out of the profits of which the 20,000*l*. for the Sloanian Museum was paid, and purchase made of a suitable building, with contiguous grounds for its reception and the lodgment of keepers.

To the north of the metropolis, about midway between the two cities of London and Westminster, there stood, in 1753, an ancient family mansion called Montague House. This is defined by Smollett in his 'History of England' as 'one of the most magnificent edifices in England.'[1] Its style of architecture was that of the Tuileries in Paris. From London it was shut off by a lofty brick wall, in the middle of which was a large ornamental gateway and lodge, through which, in my earlier years as a student of natural history, I have often passed to inspect, through the kindness of the then keepers of mineralogy and zoology, and make notes on, the Sloanian and subsequently-added rarities.

To the north of Montague House were the extensive gardens, beyond which stretched away a sylvan scene to the slopes of Highgate and Hampstead Hills.

The original location of the British Museum was more apart and remote from the actual metropolis and less easy of access than is the present Museum of Natural History at the West End.

The additions to the natural history series, which accrued from 1753 to 1833, together with the growth of other departments, necessitated provision of corresponding conservative and exhibition spaces. These were acquired by the erection, on the site of Montague House, of the present British Museum, the architect, Sir Sidney Smirke, adopting the Ionic Greek style.

The extent of space afforded by this edifice, in comparison with that of its predecessor, was such as to engender a conviction that it would suffice for all subsequent additions. The difficulty in our finite nature and limited capacity of looking forward is exemplified in such names as New College at Oxford, Newcastle, New Street, New Bridge, &c., as if nothing was ever to grow old; and the same restricted power of outlook affects our prevision of requirements of space for ever-growing collections.

The Printed Book Department, which took the lion's share of the then new British Museum, found itself compelled, in the course of one generation, to appropriate the quadrangle left by Smirke in order to admit light to the windows of the galleries looking that way or inwards.

From analogy I foresee that some successor of mine may exemplify human short-sightedness in my limit of demand to eight acres for the growth of the present Museum.

These acres, however, after conflicts stretching over a score or more of years

[1] Edition 1825, p. 332.

have at last been acquired for due display and facilities of study of the subjects of our 'Sections C and D.'

Amongst the works of architectural art which adorn the metropolis, Westminster Abbey and St. Paul's Cathedral stand supreme. Of later additions may with them be named the noble example of the Perpendicular Gothic selected by Barry for the Houses of Parliament, and I may be permitted to add, the new Law Courts, which exemplify the more severe style of the Thirteenth-century Gothic.

Mr. Alfred Waterhouse, R.A., for the realisation of the plans and requirements of our Museum of Natural History, has chosen an adaptation of the Round-arched Gothic, Romanesque, or Romaic of the twelfth century. No style could better lend itself to the introduction, for legitimate ornamentation, of the endless beautiful varieties of form and surface-sculpture exemplified in the animal and vegetable kingdoms. But the skill in which these varieties have been selected and combined to produce unity of rich effects will ever proclaim Mr. Waterhouse's supreme mastery of his art.

I need only ask the visitor to pause at the grand entrance, before he passes into the impressive and rather gloomy vestibule which leads to the great hall, and prepares him for the flood of light displaying the richly-ornamented columns, arcades, and galleries of the Index Museum.

In the construction of a building for the reception and preservation of natural history objects, the material should be of a nature that will least lend itself to the absorption and retention of moisture. This material is that artificial stone called terra-cotta. The compactness of texture which fulfils the purpose in relation to dryness is also especially favourable for a public edifice in a metropolitan locality. The microscopic receptacles of soot-particles on the polished surface of the terra-cotta slabs are reduced to a minimum; the influence of every shower in displacing those particles is maximised. I am sanguine in the expectation that the test of exposure to the London atmosphere during a period equal to that which has elapsed since the completion of Barry's richly ornamented palace at Westminster, now so sadly blackened by soot, will speak loudly in favour of Mr. Waterhouse's adoption of the material for the construction of the National Museum of Natural History. A collateral advantage is the facility to which the moulded blocks of terra-cotta lend themselves to the kind of ornamentation to which I have already referred.

In concluding the above sketch of the development of our actual Museum of Natural History, I may finally refer, in the terms of our modern phylogenists, to the traceable evidences of 'ancestral structures.' In the architectural details of the new Natural History Museum you will find but one character of the primitive and now extinct museum retained, viz. the Central Hall. In Montague House there were no galleries, but side-lit saloons or rooms of varying dimensions and on different storeys.

In its successor, the Museum developed on its site at a later period, we find galleries added: that, for example, which was appropriated to the birds and shells being 300 feet in length. This architectural organisation still exists at Bloomsbury.

The Museum, which may be said to have budded off, has risen to a still higher grade of structure after settling down at South Kensington. In its anatomy we find, it is true, the central hall and long side-lit galleries; but in addition to these inherited structures we discern a series of one-storeyed galleries, manifesting a developmental advance in the better admission of light and a consequent adaptation of the walls as well as the floor to the needs of exhibition.[1]

[1] In the notable reply (*Annales des Sciences Naturelles*, 1829) to an illustration of the unity of composition or of plan in Cephalopods and Vertebrates, by bending one of the latter so as to bring the pelvis in contact with the nape, advocated by Geoffroy St. Hilaire, Cuvier did not deem it too trivial to call in architecture to elucidate his objections. '*La composition d'une maison*, c'est le nombre d'appartemens ou de chambres qui s'y trouve; et son *plan*, c'est la disposition réciproque de ces appartemens et de ces chambres. Si deux maisons contenaient chacune un vestibule, une anti-chambre, une chambre à coucher, un salon et une salle à manger, on dirait que leur *composition est la même*: et si cette chambre, ce salon, &c., étaient au même

Should the Section, as did the Académie des Sciences in relation to the passage cited, kindly condone such application to human contrivances of the current genealogical or phylogenetic language applied to vital structures, your President need hardly own his appreciation of the vast superiority of every step in advance which is manifested in existing as compared with extinct organisms. And thus, sensible, as far as the human faculty may comprehend them, that organic adaptations transcend the best of those conceived by the ingenuity of man to fulfil his special needs, he would ask whether analogy does not legitimately lead to the inference, for organic phenomena, of an Adapting Cause operating in a corresponding transcendent degree?

In conclusion, I am moved to remark that a Museum giving space and light for adequate display of the national treasures of Natural History may be expected to exert such influence on the progress of Biology as to condone, if not call for, a narrative of the circumstances attending its formation in the Records of the British Association for the Advancement of Science.

The following Reports were read:—

1. *Report of the Committee for the Investigation of the Natural History of Socotra.*—See Reports, p. 194.

---

2. *Report of the Committee for the Investigation of the Natural History of Timor-laut.*—See Reports, p. 197.

---

3. *Report on the Record of Zoological Literature.*

FRIDAY, SEPTEMBER 2.

The following Papers were read:—

1. *Jurassic Birds and their Allies. By* Professor O. C. Marsh.

The author having been engaged for several years in investigating American Mesozoic Birds, found it important to study the European forms. He had therefore examined with some care the three known specimens of *Archæopteryx*, as well as some allied extinct Reptiles, which promised to throw light upon Birds. During this investigation he had observed several important characters in *Archæopteryx* not previously determined, and he thought it appropriate to make them known here. Among the more important of these characters were the following:—

1. The presence of true teeth in position in the skull. These teeth appear to be in the premaxillary, and in form closely resemble the teeth of *Hesperornis*. No teeth are known from the lower jaw, but they were probably present.

2. The vertebræ are biconcave. The presacral vertebræ are all, or nearly all, biconcave, resembling in form those of *Ichthyornis*. There are about twenty-one presacral vertebræ, and the number of caudals is nearly or quite the same. The sacral vertebræ are not more than five, and probably less.

3. There is a broad, well-ossified sternum. The scapular arch, as a whole,

étage arrangés dans le même manière, on dirait aussi que leur *plan est la même*. Mais si leur ordre était différent, si, de plain-pied dans une des maisons, ces pièces étaient placées dans l'autre aux étages successifs, on dirait qu'avec une composition semblable ces maisons sont construites sur des plans différens,' p. 245.

strongly resembles that in modern birds. All of the usual elements are present, and most of them are distinctly avian, the furculum especially so.

4. There are three digits only in the manus, all provided with claws. The three free metacarpals have the form and position of those in some young modern birds, and although corresponding to the same bones in reptiles, have the avian stamp already upon them.

5. The pelvic bones are separate. In this respect *Archæopteryx* differs from all adult birds recent and extinct, and agrees with Dinosaurian reptiles, a point of much importance. Diagrams illustrating this were shown.

6. The distal end of the fibula is placed in front of the tibia. This is not known in any other birds, but is a characteristic of Dinosaurs.

7. The metatarsal bones are separate, or imperfectly united. This character also has not before been observed in any adult birds, modern or ancient, but is seen in all known Dinosaurs.

The author also stated that the brain-cast of *Archæopteryx* resembled that of *Laopteryx*, an American Jurassic bird, which he had recently described. The brains of both appear to have been comparatively larger than in *Hesperornis*, which may be due to the fact that they were land birds, while all known cretaceous birds were aquatic.

The author considered the nearest allies to birds to be the Dinosaurian reptiles, which really constitute a sub-class rather than an order. Among these reptiles, *Comptognathus* is especially bird-like in the extremities, but the vertebræ and pelvis show important differences from all known birds. In examining the original specimen of *Comptognathus* in Munich, the author detected in the abdominal cavity the skeleton of a young reptile, apparently a fœtus, but possibly one that had been swallowed. Nothing of the kind had before been noticed in Dinosaurs. The presence of a clavicle in this group of reptiles had not hitherto been determined, but two specimens of *Iguanodon* in the British Museum show that this genus possessed these bones, and drawings of one were shown. The relations of Dinosaurs to early forms of birds the author had discussed in detail in his memoir on the *Odontornithes*, published during the previous year.

---

2. *On the use of the Chitinous Elements or Appendages of the Cheilostomatous Polyzoa in the Diagnosis of Species.*[1] *By* GEORGE BUSK, *F.R.S.*

Having for some time been engaged in the description of the Polyzoa collected on the *Challenger* Expedition, the author—in common, he believes, with all who have made that class the subject of study—has been greatly perplexed to find satisfactory distinctive characters in several of the natural groups composing it. Amongst the most difficult and puzzling may be more especially mentioned the generic groups comprised under the names of Cellepora, Retepora, and Cellaria or Salicornaria.

As it is but quite recently that his attention has been directed to the use that might be made of the chitinous appendages, in addition to those usually employed, derived from the calcareous skeleton, he has not been able at present to extend his observations beyond the three genera above mentioned, but he has little doubt it will be found extremely useful in many others, more especially among the *Escharidæ*.

His attention was first drawn to the use that might be made of the chitinous organs by the perusal of a short paper by Mr. A. W. Waters, in the Transactions of the Manchester Philosophical Society, on the use of the *operculum* as affording differential characters.

Led by this valuable suggestion to see how far the character of the *operculum* might assist him in the diagnosis of the species of Cellepora on which he was at the time engaged, he was at once struck with the great facility that attention to this character afforded in the distinction of otherwise obscure forms of this most difficult group.

[1] Published *in extenso* in *Linn. Soc. Journal*, vol. xv.

At the same time it appeared to him that it would be additionally advantageous, besides the characters afforded by the *operculum*, to regard those of the other chitinous organs, and notably those of the *avicularia*. In some few cases other chitinous appendages occur, but to these he need not here refer.

Not to enter into particulars, he would merely remark that, from his examination of the characters afforded by the chitinous appendages in numerous species of *Cellepora*, *Salicornaria*, and *Retepora*, he has come to the conclusion that, combining the opercular with the avicularian characters, these characters alone will, in nearly all cases in the genera mentioned, suffice to determine the species, and that with the greatest facility and certainty. He may also add, as regards the family Salicornariidæ, or Cellariidæ as some prefer to term it, this method of examination has disclosed the existence in that family of special chitinous supports, as they may be termed, on the sides or around the orifice, apparently for the articulation of the *operculum*, which, so far as he is at present aware, have not been noticed, and are peculiar to it.

As this brief notice is merely intended to draw attention to an element in the anatomy of the Cheilostomatous Polyzoa, not hitherto employed as a means of diagnosis except by Mr. Waters, he does not on the present occasion enter into details, but simply hands round specimens prepared for this method of investigation, and will conclude by a few words as to the mode in which he has found it may conveniently be carried out.

This consists, in fact, simply in the removal of the calcareous matter by means of dilute nitric or other acid, from a small fragment or portion of a zoarium, which after decalcification should be torn up or 'teased' out into minute pieces, and examined, covered with glycerine, or glycerine and gum. It is as well also, before the decalcified specimen is broken up, to stain it with some colouring matter, of which he has found picrocarmine perhaps the best.

In preparations thus made, all the chitinous elements will be found clearly displayed, and—what is of particular interest—nearly all the soft parts as well, and especially the muscular tissue; and in many cases the general conformation of the polypide may be made out almost as well, if not in some instances better, than in the recent condition.

The length of time a specimen may have been kept in the dry state, if it were in good condition to begin with, appears to make no difference in the ease with which the soft tissues may be thus, as it were, resuscitated.

We have thus in our power, from a minute fragment of a zoarium little bigger than a pin's head, to determine its specific and many other characters, in a few minutes; and, in the case of the genera above cited, with much greater facility and exactitude than by the most laborious examination of the calcareous skeleton alone.

It is much to be regretted that the method is of course only applicable to recent forms procured originally in the live state, and can afford no assistance in the case of dead or fossil forms, for the distinction of which we are so lamentably in want of sufficient means of diagnosis.

---

3. *On the Botany of Madagascar.*[1] *By* J. G. Baker, *F.R.S.*, *F.L.S.*

The fauna of Madagascar exhibits remarkable individuality of character. The island produces many striking types that are peculiar to it, and on the other hand, many widely-spread and copiously represented genera which inhabit the neighbouring continents are absent. The leading facts in connection with the subject have been fully summarised and illustrated recently by Mr. Wallace in his 'Island Life,' and the whole evidence of the fauna points in the direction of long isolation.

But when we turn to the botany, the general tendency of the facts is in a different direction, and no attempt has yet been made to summarise them. No special flora of Madagascar has yet been published, but, taking the species that have been de-

[1] Printed *in extenso* in *Journal of Botany*, beginning Nov. 1, 1881.

TABLE SHOWING THE NUMBER OF THE GENERA AND SPECIES OF EACH NATURAL ORDER OF THALAMIFLORÆ, KNOWN IN MAURITIUS, MADAGASCAR, CONTINENTAL TROPICAL AFRICA, AND INDIA APART FROM THE HIMALAYAS.

	Mauritius		Madagascar		Trop. Africa		India	
	Genera	Species	Genera	Species	Genera	Species	Genera	Species
1. Ranunculaceæ .	1	1	2	15	4	18	5	17
2. Dilleniaceæ . .	1	1	1	3	1	3	6	34
4. Magnoliaceæ . .	—	—	—	—	—	—	5	7
5. Anonaceæ . .	2	4	5	10	12	59	25	190
6. Menispermaceæ .	1	4	7	10	11	22	19	34
7. Berberideæ . .	—	—	—	—	1	1	1	3
8. Nymphæaceæ .	1	1	1	5	2	3	5	8
11. Cruciferæ . .	3	3	3	6	21	45	2	6
12. Capparidaceæ .	2	2	7	20	11	61	8	49
13. Resedaceæ . .	—	—	—	—	4	5	1	1
15. Violaceæ . . .	—	—	4	20	4	16	3	16
17. Bixineæ . . .	3	3	5	8	6	27	9	26
18. Pittosporeæ . .	1	1	1	8	1	2	1	5
20. Polygaleæ . .	—	—	1	5	3	24	5	30
21. Frankeniaceæ . .	—	—	—	—	1	2	1	1
22. Caryophyllaceæ .	2	2	2	2	12	25	7	11
23. Portulaceæ . .	—	—	1	1	2	8	2	6
24. Tamariscineæ . .	—	—	—	—	1	2	1	3
25. Elatineæ . . .	—	—	—	—	1	5	2	6
26. Hypericineæ . .	1	1	3	11	5	18	2	12
27. Guttiferæ . .	1	2	5	19	6	12	6	61
28. Ternstromiaceæ .	1	1	—	—	3	3	11	37
29. Dipterocarpeæ .	1	1	—	—	3	3	9	92
30. Chlænaceæ . .	—	—	5	9	2	2	—	—
31. Malvaceæ . .	7	7	10	28	17	88	20	85
32. Sterculiaceæ . .	6	13	6	22	14	51	16	79
33. Tiliaceæ . .	2	3	4	15	10	70	13	109
34. Linaceæ . . .	2	4	2	6	6	14	6	18
35. Humiriaceæ . .	—	—	—	—	1	1	—	—
36. Malpighiaceæ . .	—	—	2	4	5	14	3	10
37. Zygophylleæ . .	1	1	1	1	5	14	4	8
38. Geraniaceæ . .	2	3	4	15	6	39	7	101
39. Rutaceæ . . .	3	7	2	2	4	12	19	70
40. Simarubeæ . .	2	2	1	1	9	11	9	16
41. Ochnaceæ . .	1	1	2	9	2	19	4	11
42. Burseraceæ . .	2	2	1	1	4	9	10	39
43. Meliaceæ . .	2	4	1	5	5	15	19	83
44. Chailletiaceæ . .	—	—	1	8	1	15	1	6
45. Olacineæ . .	3	3	3	3	15	26	23	65
46. Ilicineæ . . .	—	—	1	2	1	1	1	14
47. Celastrineæ . .	3	3	7	22	6	44	18	85
49. Rhamneæ . .	4	5	6	15	8	12	11	40
50. Ampelideæ . .	2	3	2	12	2	78	3	75
51. Sapindaceæ . .	8	11	9	11	13	37	20	55
52. Sabiaceæ . .	—	—	—	—	—	—	2	9
53. Anacardiaceæ . .	3	5	7	14	11	31	18	93
55. Moringeæ . .	—	—	1	1	1	1	2	1
	—	—	126	350	—	—	—	—

scribed in general monographs and scattered papers, and adding to them those that we possess in the London herbaria alone, we have now definite knowledge from Madagascar of not less than 2,000 species, which the author estimates represent 700 genera and 125 natural orders. The flora, as a whole, follows closely the same general lines as that of the other tropical countries of the old world. This may be illustrated in various ways. The annexed table gives the number of genera and species of each order in Madagascar as compared with Mauritius, continental tropical Africa, and India, apart from the Himalayas, and it will be seen that the general parallelism is very close.

Out of 55 known orders of Thalamifloræ only eight are not here represented; but of these 47, 37 are already known in Madagascar. Of the ten orders not yet known in Madagascar, none are known in Mauritius, but two are represented by single species in the Seychelles. Two of them are confined to Tropical Asia and one to Tropical Africa, but the other seven are common to both continents.

One of the most striking and suggestive characters of the flora of the intertropical zone of the world, taken as a whole, is the large extent to which it is everywhere made up of species representing large genera which are spread through it pretty evenly. There are many genera containing 300, 400, or 500 species, that are largely represented in Africa, Asia, and America. Some of these are herbaceous glumiferous monocotyledons, as, for instance, Cyperus with 400 species, and Panicum with 500. The large genera of ferns, such as Polypodium, Acrostichum, Asplenium, and Pteris, all fall into this category. Some of them are dicotyledons with separated sexes and small inconspicuous flower-wrappers, such as Ficus with 400 species, Piper with 600, Phyllanthus with 400–500, Croton with 450. But many of these large cosmopolitan genera are dicotyledons of shrubby or arborescent habit, with insect-fertilised hermaphrodite flowers, a distinct calyx and corolla, and showy, scented petals. Loranthus with 300 species, although exclusively parasitical, falls into this category. So do Psychotria with 500 species, Indigofera with 300–400, Vernonia with 400, Solanum with 500, and Eugenia with 500. And a point which must be prominently taken into account in estimating the general relations of the flora of Madagascar, is that nearly all these large cosmopolitan genera are now ascertained to be represented in the island, although often by endemic species.

The marked tendency to uniformity in character which is shown by the flora of the whole tropical zone is further illustrated by the fact that a considerable number of species are spread universally through the old world, and that a considerable number extend their range to Tropical America. Of the plants of our own colonies in that part of the world, out of 1,058 flowering plants and vascular Cryptogamia, 370, or about one-third, occur both in Tropical Asia and Continental Africa, and 225 species, or about one in five of the total flora, extend their range to Tropical America. In Madagascar the absolute number of these widely-spread species is as great, but of course the proportion which they bear to the total flora is smaller. The orders most largely represented here are Cyperaceæ, Gramineæ, Compositæ, Leguminosæ, and Malvaceæ.

In the island flora there are altogether about 80 endemic genera, according to our present knowledge. The order Chlænaceæ has been supposed to be peculiar to Madagascar, but two of the genera have been found in Mozambique. The other genera are many of them monotypic, and very few contain more than three or four species. They are not concentrated in any part of the systematic series, and most of them belong to the large natural orders, Compositæ with nine genera, and Rubiaceæ with eight, taking the lead.

With Mauritius, Bourbon, and the Seychelles the affinity of the Madagascar flora is close. There are several genera and species which occur both in the large and small islands which are restricted to the group.

There is a close affinity between the flora of Madagascar and that of Tropical Africa. In Rubiaceæ, for instance, there are nine genera otherwise confined to Tropical Africa which reach Madagascar, and in other orders a smaller number. We have instances of such genera in Brexia, Dombeya, Acridocarpus, Psorospermum, Myrothamnus, Psiadia, Landolphia, and Mimulopsis. Instances of striking species common to both areas are furnished by Haronga madagascarensis, Trachylobium Hornemannianum (the Copal tree), Albizzia fastigiata, and Eriosema cajanoides.

There are a few cases of curious affinities between Madagascar and Tropical Asia. Of the pitcher-plants, which occur in India and are concentrated in the Malay Archipelago, one species occurs in the Seychelles, and another in Madagascar, but they fail to reach Continental Africa. Of the curious genus Tambourissa there are about a dozen species in the Mascaren Isles, and one in Java, but none elsewhere. But when we remember what has been already pointed out, as to the uniformity of the flora of the whole tropical zone, it would seem to be unsafe to infer from these cases that there has been any comparatively recent land-connection between the Mascaren Islands and Tropical Asia.

A very curious peculiarity of the flora of the hill country of Central Madagascar is the affinity which we may trace with that of the Cape. For instance, the heaths, of which there are some 500 at the Cape, are represented in Madagascar by about a dozen species, all endemic. Instances of characteristic Cape genera which reach Madagascar are found in Selago, Aristea, Geissorhiza, Chironia, Pachypodium, Harveya, Dais, Lasiosiphon, Disa, Satyrium, and Mohria. There are also a few curious cases, as instanced in Viola abyssinica, Geranium simense, Agauria salicifolia, Caucalis melanantha, and Antherotoma Naudini, where species are found nowhere else except in Central Madagascar and the high mountain regions of Central Africa, such as the Camaroons and Abyssinian Highlands.

---

4. *On the Colours of Spring Flowers.* *By* Alfred W. Bennett, *M.A., B.Sc., F.L.S.*

The variation in the predominant colour of our native flora as the spring advances to summer and autumn is a familiar fact, though the author is not aware that any attempt has been made to tabulate the phenomena, or to reduce them to a general law.

The list from which the following statistics are obtained is based (with a very few corrections) on the time of flowering given in Sir J. D. Hooker's 'Student's Flora,' the same work being also followed in the limitation of species. Those are regarded as early spring flowers which begin to blossom not later than April. In order to prevent the element of error in the average of colour which would result from the inclusion of all wild plants, whether common or rare, all are excluded from the list which do not bear at least as high a number as 50 in the 'London Catalogue of British Plants.' For the classification of the colours, the flowers are arranged under five heads, viz., 1. white; 2. green; 3. yellow; 4. red and pink; 5. blue and violet; very slight shades of colour being neglected. Several large orders in which the flowers are very inconspicuous are entirely passed over, viz., the Amentiferæ, Juncaceæ, Gramineæ, Cyperaceæ, and Coniferæ.

The analytical table thus prepared shows that out of 64 species of common early spring flowers, 26, or 40·5 per cent., are white; 9, or 14·1 per cent., green; 13, or 20·3 per cent., yellow; 5, or 7·8 per cent., red or pink; and 11, or 17·4 per cent., blue or violet. As compared with summer or autumn flowers, this list shows a remarkable preponderance of white flowers; yellow is also greatly in excess, as compared with other periods of the year, while the number of red and pink flowers is extremely small.

In order to compare the colour of early spring flowers in England with those of Switzerland, the author has taken the two volumes already published, including 200 species, of Seboth's 'Alpine Plants,' May, instead of April, being regarded as the latest early spring month. The following are the results. Out of 51 species, 18, or 35·3 per cent., are white; 1, or 2·0 per cent., green; 10, or 19·6 per cent., yellow; 14, or 27·4 per cent., red or pink; and 8, or 15·7 per cent., blue or violet.

Several points of contrast between these lists will at once suggest themselves, especially the smaller proportion of white, and the very much larger proportion—amounting to nearly fourfold—of red and pink flowers, in the second as compared with the first.

In attempting to reduce these facts to a general law, it must first be borne in mind that the two colours white and green stand on a different footing from the rest, and indicate more correctly an absence of colour. The colour of green petals is not due to a mixture of blue and yellow pigments, but to the presence of chlorophyll; and white flowers do not owe their colour to a milk-white fluid, but to the presence of air in the cells of the petals. Seeing that the bright-coloured fluid pigments are formed only under the influence of a sufficient supply of light and heat, the large proportion of green and white early spring flowers is easily accounted for. With regard to yellow, M. Flahaut states that 'a solid insoluble pigment, the *xanthine* of Frémy and Cloëz, is, in the first place, to be distinguished from all the soluble colouring matters, blue, yellow, red, and their mixtures, all of which are acted on very readily by reagents, and which are usually found only in the epidermal cells.' This xanthine Frémy states to occur always in 'the form of clearly defined grains, occasionally in the epidermal, much more often in the deeper-lying cells, slowly soluble in alcohol and potassa. It is, in all probability, a modification of chlorophyll.' A list of plants, in the petals of which he has detected this substance, are without exception early-flowering. The colours, therefore, which pre-eminently distinguish our summer and autumn flora—the reds, pinks, blues, and some yellows—are due to coloured soluble pigments which require both a strong light and a high temperature for their production, and Batalin has shown this to be especially the case with the red colouring-substance. That the same species of flower frequently assumes a more intense colour with increasing altitude in the Alps has been shown by the observations of M. Bonnier, who states that this change is due to an actual increase in the amount of colouring matter in the cells. The difference between the prevailing colours of the ordinary spring flora in England and in Switzerland is probably due to the same cause. Owing partly to the spring being a month later, partly to the more southern latitude and consequent greater elevation of the sun, partly to the clearer air of a high altitude, the light which opens the earliest spring flowers is much stronger in Switzerland than in England, causing the appearance of those brilliant roses and pinks of the Silenes, Ericas, and Primulas, and blues of the Gentianas and Soldanellas, with which we have scarcely anything to compare in our spring flora. The most striking feature of the early spring Swiss flora, in the figures already given, is the very large ingredient of red and pink. The author believes a more extensive analysis would show an almost equal preponderance of blue.

---

5. *On the Constancy of Insects in their Visits to Flowers.* *By* Alfred W. Bennett, *M.A., B.Sc., F.L.S.*

This paper contains a record of observations made with the view of serving as a contribution towards the determination of the question whether insects are altogether indiscriminating in their visits to flowers, or whether on the same journey they confine themselves exclusively or chiefly to one species. For this purpose points of observation were chosen where a considerable number of different flowers grew in profusion and intermixed, so that the insect would have abundant opportunity of changing its diet if so disposed. The insects observed were Lepidoptera, Apidæ, and Syrphidæ. Their flight was watched, and the flowers recorded on which they successively settled; the pollen attached to the body and legs of the Apidæ, and that contained in the abdomen of the Syrphidæ, being also examined.

As far as this series of observations goes, no general statement can be made as to the constancy of insects in visiting the same species of flower during the same flight. A decided preference for successive visits to the same flower was unquestionably shown in many instances, and this is not dependent on the colour of the flower only. The hive-bee appears to be far the most constant in this respect—often absolutely so—other Apidæ approaching, but not usually equalling it. From their strong and rapid flight, and the extremely hairy covering of their abdomen and legs, this class of insects is probably the most efficient agent in the dissemination of pollen. The Syrphidæ, which also visit flowers in great abundance, are much less constant; but their object is not so much honey as the pollen itself, which forms the principal article of their food; and their body and legs being not nearly so densely clothed with hairs, their share in the carriage of pollen must be much smaller. The Lepidoptera appear to vary greatly in their habits. As far as can be gathered from the few observations made, the 'painted lady' (*Cynthia cardui*) and the small tortoise-shell (*Vanessa urticæ*) are very constant; while the whites, the blues, and the browns are far more catholic or less discriminative in their tastes. It is open to question, however, whether more than a very few flowers are dependent on butterflies for their fertilisation. At all events, their visits to flowers are often only interludes in their settlement on grass, leaves, the stems of trees, or the bare ground.

---

6. *On the Mode in which the Seed of* Stipa *buries itself in the ground.* *By* Sir JOHN LUBBOCK, *Bart., M.P., F.R.S.*

The author commenced by pointing out how the structure of seeds served for purposes of dispersion, accounting thus for the winged seeds of many trees, the fleshy pulp of fruits, the hooks on many seeds, the sticky surfaces of some, and the delicate feathery parachutes of others; and then, after referring in a few words to the cases in which plants throw their own seeds—as for instance, the Violet, Oxalis, Geranium, Broom, and others—sometimes as far as twenty feet, he passed on to the cases in which seeds sow themselves in the ground.

After mentioning the subterranean clover, the ground-nut, cranesbill, &c., he exhibited the very curious seed of *Stipa pennata*, a kind of grass, which was also illustrated by a diagram. The whole seed is more than a foot long, and consists of four parts—firstly, the actual seed, which is about half an inch in length, narrow, pointed, and provided with short, stiff, recurved hairs. The upper end is prolonged into a stiff, twisted, corkscrew-like rod, about two inches in length; then, at an angle, is a straight piece about $\frac{3}{4}$-inch long; and then a beautiful tapering feathered awn, nearly an inch in length. Mr. Francis Darwin had suggested that this beautiful seed buries itself by hygroscopic action, as Roux has shown to be the case with the cranesbills, the 'corkscrew' twisting and untwisting under the influence of different degrees of moisture. The author, however, gave reasons for thinking that the true, or at any rate, more usual motive power, was the wind, which acting on the feathery awn, twists the corkscrew round and round, and drives it into the ground. At any rate, in some cases this is the mode of action, and by means of a small bottle filled with moss, and a fan, he exhibited the movement to the Section experimentally.

SATURDAY, SEPTEMBER 3.

The following Papers were read:—

1. *On the Insect House in the Gardens of the Zoological Society of London.* *By* P. L. SCLATER, *M.A., Ph.D., F.R.S., Secretary to the Zoological Society of London.*

The author called the attention of the meeting to the important addition that had been made during the present year to the Collection of living animals in the Gardens of the Zoological Society of London, in the shape of an Insectarium or house for the exhibition of living insects in all stages of their development.

He stated that, although of late years many entomologists had been in the habit of rearing insects in captivity for the purpose of watching their transformations and obtaining good specimens in each stage of existence, nothing like a systematic attempt, so far as he knew, had been made to form a general collection of living insects for exhibition. As in former days, as regards reptiles and the lower marine animals, so in the present instance as regards its Insectarium, the Zoological Society of London seemed to be first in the field, and—so far as could be judged from the progress already made—to be likely, if not altogether successful, to attain many interesting and instructive results.

The building used as an Insectarium was constructed of iron and glass on three sides, with a brick back to it. The cases containing the insects were arranged on stands all round the building, and also occupied two tables in the centre. The cases used for the principal specimens were formed of zinc plates and glass. The upper part of them was glazed on all four sides, the top being formed of perforated zinc, so as to admit the air. The food-plant, or the object required for the suspension of the chrysalis, when that stage of the insect is exhibited, was inserted into the case through a circular hole in the bottom; but the glass front also opened, so that ready access was obtainable to the interior. The larger cases in the front row measured about 24 inches in breadth by 18 in depth, and were 32 inches in height. The cases in the opposite row were of similar construction, but rather smaller in dimensions.

The following was a list of the insects that had been bred in the Insect-house during the present season, and of which specimens were exhibited to the meeting.

List of Lepidoptera reared in the Insect House at the Zoological Society's Gardens.

DIURNI.

Papilionidæ.
Papilio machaon.
Pieridideæ.
Pieris cratægi.
Anthocharis cardamines.
Vanessidæ.
Argynnis paphia.
„ „ var. valezina.
„ aglaia.
Melitæa maturna.
„ cinxia.
Vanessa urticæ.
„ atalanta.
„ antiopa.

Nymphalidæ.
Limenitis sibylla.
Apatura iris.
„ ilia.
Satyridæ.
Arge galathea.
Erebia medea.
Lycænidæ.
Thecla quercûs.
Polyommatus phlæas.
Lycæna corydon.
Erycinidæ.
Nemeobius lucina.

NOCTURNI.

SPHINGES AND BOMBYCES.

Sphingidæ.
Deilephila euphorbiæ.
Lithosiidæ.
Lithosia quadra.
Eucheliidæ.
Callimorpha dominula.
Cheloniidæ.
Chelonia caja.
„ villica.
Liparidæ.
Liparis monacha.
Bombycidæ.
Odonestis potatoria.

Lasiocampa quercifolia.
Saturniidæ.
Saturnia carpini.
Attacus atlas.
„ mylitta.
„ cynthia.
„ pernyi.
„ cecropia.
Samia gloveri.
Telea promethea.
Actias selene.
„ luna.
Antheræa yama-mai.

GEOMETRINA.

Uropterygidæ.
Uropteryx sambucata.
Ennomidæ.
Ellopia fasciaria.

Boarmidæ.
Tephrosia biundularia.
Cleora glabraria.

NOCTUÆ.

Catocalidæ.
Catocala sponsa.

2. *On the Birds which have bred in the Barnsley and South Yorkshire District. By* Thomas Lister.

The district of the author's observations is that part of the county of York called the South Yorkshire coal-formation, chiefly between the Calder on the north, and the Don, west and south, with the Dearne, its tributary, flowing through the middle region by Barnsley, the central point of observation. The country extends, in a series of well-wooded undulations, from the magnesian limestone on the east at about 300 feet elevation, to the millstone grit, from 1,000 to 1,700 feet, which it attains at Black Tor, north-west of Sheffield. The birds may be said to be characteristic of the varied districts, from the sub-alpine regions west (the Pennine range, or great backbone of England, where the moorland birds predominate), the woodland and cultivated grounds in the centre, frequented by our resident song-birds and migratory warblers, to the lower tracts beyond the magnesian limestone in the south-east of the Riding, where birds of the marsh and tidal rivers mingle with the inland birds. In this paper there is not space to give dates, places, and authorities, except in some remarkable or recent instances. He believes additions could be made to the list of birds breeding in the district, by observation or enquiries respecting the moorland and marsh regions. One main object the author has always kept in view is, to show what birds have been known in past times, what have been lost to modern observers, and what we might still possess, to gratify the field-naturalist, if means were taken by public Acts, by protection societies—which have done good as far as they have gone—and by proprietors like the late Charles Waterton and the owner of Wentworth Castle, F. V. T. Wentworth, Esq., and other landowners, to encourage the preservation of our lessening rare birds.

In the list appended to the longer article it will be seen that there are a few birds extinct, or nearly so, in South Yorkshire. The only one which is quite lost to us—the kite—he is justified in introducing here. Its nest and young were taken by his elder brother in his school-days; it is also recorded by the late Dr. Farrar in the same woods, two miles from Barnsley. The author quoted from his list, written in 1844, in his paper on the birds of the West Riding, delivered at the British Association meeting at Bradford, inserted in its 'Transactions' for 1873. Dr. Farrar records also the peregrine falcon in the same woods and at Walton. The veteran Waterton complained to him then, and since to the author, of the gradual disappearance of these and other members of the falcon family from the grand lake and woods of Walton.

The list of birds breeding in this part of Yorkshire is of course much fewer than that of birds which have occurred. To give a brief *résumé* we may divide them, as is sometimes done, into land and water birds. Of the former there are 92: 11 raptorial or birds of prey; 73 insessorial or perching and climbing birds; 8 rasores or scratchers. Of water-birds there are 21, of which 13 are waders and 8 swimmers, making 92 in all. The most rare of these are the greenshank, of which only a few instances of nesting are recorded; the red-backed shrike, of which the old and young were snared by Dr. Farrar in Cliffwood, one mile from Barnsley, in 1829; the reed-warbler at Walton Hall, Hemsworth Dam, Thorne Moor, &c., the stone-chat on Brierley Common, and towards the moors westward; the woodlark, a few surviving in the south of the county; the mealy redpoll, the dunlin, the marsh, and Montague's harrier (occasionally occurring about Thorne, Doncaster, Sheffield); the green woodpecker, wryneck, lesser spotted woodpecker, turtle-dove. The pied flycatcher occurs locally at Wentworth Castle, Cannon Hall, and Wharncliffe woods. These are sufficient to indicate that some rare birds may yet be found.

---

3. *On the Foot of Birds, and on the Use of the Serrated Claw.*[1] *By* Philip M. C. Kermode.

As regards the serration, the following characters appear to be constant. It is on the middle toe of each foot, which is longer than the other toes; the serration is

[1] The original paper was published in the *Isle of Man Times* of Saturday, Sept. 17, 1881.

that of an edge on the inner margin of the claw, being in the horny sheath, but not appearing in the bone; it is on a plane with the upper or concave surface of, and projecting at right angles to the inner side of the claw, the teeth being directed forwards and slightly curved towards their points; it is not found on the claw of young birds, but grows with the growth of the bird.

Possessed of this peculiarity we find representatives of the following families:—1. *Strigidæ* (Swainson mentions *Strix flammea*, but the author has not detected it); 2. *Caprimulgidæ*; 3. *Charadriidæ*; 4. *Ardeidæ*; 5. *Pelecanidæ*.

That it is not caused by 'wear and tear' is evidenced by the constancy of its position, and the regularity, size, and shape of the teeth.

It cannot serve the bird in seizing or retaining its prey, nor yet in retaining its perch (unless, possibly, with the *Caprimulgidæ*, which perch along a branch, having one foot placed before the other).

Possibly the birds possessed of this form may, from food or habit, be more subject to parasites, or these be of a peculiar nature. Whether this be so or not, the proper function of this peculiar form of claw is evidently to cleanse and preen the plumage, and, with the *Caprimulgidæ*, to keep clean the vibrissæ.

MONDAY, SEPTEMBER 5.

The following Papers and Report were read:—

1. *On the Anatomy and Classification of the Petrels, based upon those collected by H.M.S. 'Challenger.'* *By* W. A. Forbes, *B.A.*, *F.L.S.*, *F.Z.S.*

After stating the reasons why hitherto the anatomy of this group of birds had been hardly at all studied, the author, who has been enabled, thanks mainly to the specimens collected by the *Challenger*, and entrusted to him for anatomical examination by Sir Wyville Thomson, to dissect nearly all the chief genera of this group, proceeded to give an account of the results as yet arrived at.

After describing briefly some of the more remarkable peculiarities of structure of the group of Petrels or *Tubinares*, of which about 150 species are now known, the author proceeded to consider the questions of their classification and affinities. The *Tubinares* form a very well-defined group, separated off from all other birds by a combination of characters external and internal, not found elsewhere, as well as by some peculiar to the group itself. Two well-marked families now exist: one, the Oceanic Petrels (*Oceanitidæ*) represented by four genera, and about eight species; the other (*Procellariidæ*) containing all the remainder of the group, and being divisible again into three sub-families, the Albatrosses (*Diomedeinæ*), the Diving Petrels (*Pelecanoidinæ*), and the true Petrels (*Procellariinæ*), this last division containing by far the greater number of the genera and species.

As regards the affinities of the group, the author was of the opinion that the Petrels are probably much modified descendants of some ancient form, which was related to the Ciconiiform birds of Garrod, *i.e.* the storks, American vultures, *Accipitres*, *Steganopodes*, and their allies. Any relationship to the gulls (*Laridæ*) was not borne out by the anatomy of the two groups in question.

---

2. *On some Permanent Larval Forms among the* Crinoidea. *By* P. Herbert Carpenter, *M.A.*

Since the discovery of the pentacrinoid stage in the development of the featherstar, the stalked Crinoids have been universally regarded as occupying the position of permanent larval forms with respect to the *Comatulæ*; and the discovery of types like *Rhizocrinus* and *Hyocrinus*, in which the oral plates are more or less completely retained through life, has confirmed and extended this view. In these recent forms the oral plates separate from one another, as they do in the later stages of the pentacrinoid larva of the feather-star, and the peristome is laid open to the exterior. But in many Palæocrinoids the peristome was covered in throughout life, either by a pyramid of oral plates, or by a 'vault' of greater or less complexity.

De Loriol has recently described a small Jurassic Crinoid—*Thiollierícrinus*—in which the top stem joint enlarges and bears cirrhi, just as in *Comatula*; but it retains its connection with the stem below it, instead of becoming free, and the basals do not entirely disappear from the exterior of the calyx. *Thiollierícrinus*, therefore, is permanently in the condition of a tolerably advanced pentacrinoid larva of the feather-star.

Among the *Comatulæ* dredged by the *Challenger* and by the United States Coast Survey are three species of a new genus which the author proposes to call *Atelecrinus*. Two species were obtained in the Caribbean Sea, and the third in the South Pacific. The distinctive characters of the genus are (1) the persistence of the embryonic basals, which do not undergo metamorphosis into a rosette, but remain as a closed circlet, entirely separating the radials from the centro-dorsal; (2) the absence of pinnules from about the first eleven arm-joints. With the exception of the doubtful genus *Comaster*, no recent *Comatula* yet known retains its embryonic basals on the exterior of the calyx, after the latter part of its existence, as a 'Pentacrinoid;' while there is no *Comatula* hitherto known, either recent or fossil, in which the basal circlet is complete, as it is in some *Pentacrinus* species, and in the earlier stages of the Pentacrinoid. As regards the characters of its calyx, therefore, *Atelecrinus* may be considered as a permanent larval form. The absence of pinnules from the basal portions of the arms points to the same conclusion. The author has met with five *Comatula*-species which agree with *Ant. rosacea* in not developing pinnules upon the lower arm-joints until after the appearance of cirrhi upon the centro-dorsal and its liberation from the rest of the larval stem; but *Atelecrinus* appears to be permanently in this condition. It exhibits no traces, however, of persistent oral plates.

---

3. *Note on the British* Comatulæ. *By* P. Herbert Carpenter, *M.A.*

Some years ago Barrett dredged a *Comatula* on the coast of Skye, to which he gave the specific name *celtica*. His specimens were lost for a time, and though others were obtained from the same locality by H.M.S. *Porcupine*, there has been a little uncertainty, especially among Continental zoologists, as to the true characters of the species. Recently, however, one of Barrett's original specimens has been discovered at the British Museum, and it turns out to be identical, as do the *Porcupine* specimens, with the rare *Antedon phalangium* of the Mediterranean. This species, however, is not known to occur at any intermediate localities between Skye and the Mediterranean. Neither has it been obtained further north than the Faroe Channel. The *Antedon celtica*, described by Von Marenzeller and Sladen from the Arctic Ocean, is an entirely different species, and is the one to which this name will have to be applied in future; Müller's name, *phalangium*, having a priority of several years over *celtica*, Barrett. Besides *Ant. phalangium* and *Ant. Sarsii*, which has been obtained in the Shetlands, there are, perhaps, two other *Comatulæ* which are known on our coasts. One is the common *Ant. rosacea*, which is universally distributed, and the other is *Ant. Mülleri*, which is distinguished from *Ant. rosacea*, according to Sir Wyville Thomson, by the greater length of the ovaries, and a difference in the relative proportions of the lower pinnules. This type has been obtained at Arran, Oban, Belfast, and elsewhere, and it is the one which seems to be the most common in the Mediterranean. Whether, however, it is really distinct from *Ant. rosacea* is a point for further investigation.

---

4. *On the Affinities of Proneomenia.*[1] *By* Dr. A. A. W. Hubrecht.

One of the forms of animal life which have been looked upon as aberrant by successive investigators of mollusks and collectors of shells is the genus Chiton, with its allies, Chitonellus, Cryptochiton, &c. Instead of a regular bivalve or univalve shell these animals carried along the median line of their backs a series of calcareous plates, forming, on closer inspection, so many separate shells, the one behind the other.

By the possession of a radula, they appeared closely allied to the other *Odontophora*; by a certain amount of bilateral symmetry they seemed to resemble the lamellibranchiates.

Very recently certain points in their internal organisation, more especially concerning the nervous system, gave rise to their being entirely removed (wrongly I think) by a German morphologist from the Mollusks and placed in the sub-division of Worms.

Of late years other, yet more perplexing, forms have come to light. One of them, discovered by Professor Lovén, of Stockholm, appeared to be a very small-sized worm, and was, up to the last two or three years, arranged with the Gephyreans, and called *Chætoderma*. Its anatomy was first investigated by Professor von Graff, and more completely in 1877 by Dr. Hansen.

The second genus to which I allude was first described by Tullberg, in 1875, found off the Swedish and Norwegian coast, and lately proved, by the Rev. A. M. Norman, also to inhabit the British coasts. To it the name of Neomenia was assigned.

Opinions differed as to its nearest allies. Some placed it with the worms, others with the mollusks. Von Graff pointed out its close relationship to Chætoderma, whereas the distinguished British morphologist, Professor Ray Lankester, created a separate phylum for it, which he placed in the immediate vicinity of the Chitons.

Von Thering was the first to propose that the Chitons, Chætoderma, and Neomenia should all be united in a separate class, which he called the class of the *Amphineura*.

The year before last the Dutch expedition which, in the vessel *Willem Barents*, yearly sets out for explorations of the Arctic seas, brought with it two specimens of an animal, which not only proved this arrangement to be a very natural one, but also by its minute anatomy actually furnishes several links by which the disconnected genera above mentioned are held together.

The specimens were placed in my hands, and, in working them out, I was more fortunate than several of my fellow-workers in this one respect, that my results were not forestalled by the publication of an English report on the same subject which appeared last year, and in which some of the most eminent of your specialists described the different marine animals *brought home by the Dutch exploring vessel* from a collection of specimens which had found their way to the Exeter Museum!

The comparative study was unexpectedly facilitated by the kind generosity with which Professor Ray Lankester, who had made an excellent series of sections through the specimens of Neomenia collected by Mr. Norman, put these sections at my disposal, although his intention in preparing them had been to work up the subject himself.

I may now call your attention to those facts by which either the affinity of the different genera of the Amphineura is demonstrated, or even in some cases light appears to be thrown on the phylogeny of the Mollusca in general.

The external shape is very simple, in which respect it corresponds with Neomenia and Chætoderma; in size, however, it considerably surpasses them, measuring about 15 centim.; the body is rounded, shows no external appendages whatever, whereas ventrally a very fine groove is perceptible, in front and behind of which the anterior and posterior openings leading into the animal's intestines are situated.

[1] Published in the Supplement Band zum *Niederländischen Archiv. für Zoologie*. Leyden. 1881.

Inside the fine groove, which in life can, no doubt, be opened and expanded, a longitudinal ridge is situated, which is coated with cilia, protrusible in its turn, and most probably the homologue of the foot in other Mollusca.

On touching the exterior surface of the animal it feels rough and stiff; this is caused by innumerable small spiculæ in its integument, which are intermixed, in a more or less regular arrangement, and several layers of which are superposed one upon the other. They are calcareous, supported by and formed in a sort of cellular cup surrounding the base, which remains in communication with the deeper cellular layers of the integument. Between them a homogeneous chitin-like substance is present, holding them in their places.

Similar structures may be noticed in the integument of Chiton on the sloping sides of the mantle laterally with the dorsal plates, and these structures are, perhaps, more marked in young than they are in older stages.

In Chitonellus, where the dorsal plates are considerably reduced, they were found in a much greater number by a German searcher, several years ago. Similar calcareous spicules, differently arranged and shaped, however, are present in Chætoderma and Neomenia.

With reference to the digestive canal, which is wholly symmetrical, I have little to remark. It is internally provided with deep folds, and part of it is strongly ciliated, in both respects closely resembling Neomenia. Neither could a separate liver be detected, special secreting cells in the walls of the intestine apparently supplementing the functions of this organ. Internally the mouth is surrounded by circular or semicircular folds of the pharyngeal epithelium; one of these is provided with numerous nerve-branches running towards it, and must be looked upon as a sort of circular lip. Over the muscular buccal mass a curious blind prolongation of the posterior thin-walled portion of the intestine takes its course; this terminates anteriorly in the head. Posteriorly on the floor of the buccal mass a small slit-like opening is found, leading into a median cavity containing the radula and into two lateral tubes, the salivary glands. As Neomenia is entirely deprived of a radula, and was for this reason removed from the Mollusks, it is important to notice that its close ally, Proneomenia, is possessed of one. It is also a very suggestive fact that the radula of this latter form, though perfect and complicated in shape, is so extremely diminished in size that it may be said to be degenerate and on its way to be lost, a stage which has been reached in Neomenia. For this reason the apparently less differentiated Neomenia may not be looked upon as the more primitive; the important ancestral character which it has lost is, however, retained in its ally, and this induced me to choose the name of Proneomenia for the latter.

In passing on to the nervous system, always so important in classification, a general remark may be made respecting a more primitive characteristic of the nerve-tissue of this animal. Although both ganglia and nerve-stems are present, still the latter are everywhere accompanied by nerve-cells, which in the ganglia are more numerous.

The brain is situated close to the front termination of the body, and three principal pairs of nerves originate from it, one pair forming the sublingual ring, the others being continued in the longitudinal pedal and longitudinal lateral stems. The two pedal nerves are united by transverse commissures, such as were noted for Chiton and Neomenia. In Chiton this was inadequately interpreted as an approach to what is called in German the *Strickleiternerven-system* of segmented invertebrates. Traces of it were found in such lower Mollusks as Haliotis and Fissurella; its increased complication in the Amphineura nevertheless shows it to be of importance in determining the phylogenetic affinities of these animals. Moreover Proneomenia in another important character shows a greater complication, viz. in the presence of a system of transverse commissures between the lateral and the pedal stems. As numerous finer branches spring from these transverse commissures, as well as from the longitudinal stems, a gradual approach is here noticeable towards that form of nervous system which has been described by Lang for marine flatworms, in which a dendritic and general anastomose of commissures in the most different directions is present, and further on to a still more primitive stage, in which even the meshes between this network of nervous tissue are filled up, and in which a continuous plexus of nervous tissue pervades throughout the body, as some time ago it was found to exist in Actiniæ and in certain Nemerteans.

Lastly, another not unimportant fact may be noticed: viz. that here the three principal pairs of nerves separately originate from the brain, which is not the case in the other Amphineura.

The organs of reproduction and of excretion of Proneomenia are in many respects highly suggestive.

The hermaphrodite gland is situated all along the back of the animal; it is very symmetrical and intrinsically double. The generative products are carried by two ciliated canals, which are the direct continuation of the double gland, into a cavity, the pericardium. This pericardium in Mollusks is the representative of the body-cavity: in Chætoderma and Neomenia it equally serves as a receptacle for the eggs. Inside this cavity in all the three genera the heart is situated, and caused the ill-chosen name of pericardium to be given to this reduced portion of the body-cavity.

Another set of ciliated ducts leads the genital products out of the pericardium towards the exterior. They are of different diameter and make a double bend. A paired additional gland which is ramified opens out into them. The terminal thicker portion of the ducts leading outwards has a high epithelium in which spherical secretions take their origin. It is marked off by a muscular constriction from the parts preceding it, and must, as it appears to me, be looked upon as the renal organ, the kidney, of the animal. Both halves of it coalesce and then open to the exterior.

In this direct and serial continuity between the three cavities (*a*) of the genital gland, (*b*) of the pericardium, and (*c*) of the kidney or nephridium, I believe we have an important fact before us for the comparative morphology of the Mollusks. Now we must bear in mind (1) that in the greater number of Mollusks a communication between the renal organ and the pericardium (*i.e.* between the nephridium and the body-cavity) persists. Secondly, that the genital products, which are generally carried outwards independently, are, on the contrary, evacuated into the cavity of the kidney in such more primitive Mollusks as *Dentalium*, *Fissurella*, *Patella*, and *Spondylus*. To me it appears that even this is only a secondary stage, and that the primitive one was that in which the genital products, being discharged into the body-cavity, were from thence conveyed outwards by the ciliated nephridium.

This is, in fact, the arrangement as it still obtains in Proneomenia, and which is most likely to be found in Chætoderma and Neomenia as well.

I will only add that the anatomical details, which we have just passed under review, were none of them studied by direct macroscopic preparation. With specimens of this rarity it seemed preferable to cut them up into series of sections which could all of them be preserved, afterwards reconstructing the original shape by mental combination of the sections. This permits of all the anatomical statements being submitted to revision or criticism at any time, by the aid of the original preparations.

---

5. *Report on the Migration of Birds.*—See Reports, p. 189.

---

6. *On some Points in the Development of* Osmunda regalis (*Linn.*). *By* Chas. P. Hobkirk, *F.L.S.*

The object of this paper was to draw attention to the fact that *Osmunda regalis* requires six years to attain its normal development into the perfect spore-bearing plant. The author showed dried specimens of the various stages of this development, describing their details, and showing how each year produced a plant gradually approaching towards the perfect form, and also exhibited a six-year-old growing plant, producing spores for the first time. He also exhibited a portion of a barren frond, in which some of the terminal pinnæ were much constricted in their development, and bearing spore-cases or thecæ on their margins.

TUESDAY, SEPTEMBER 6.

The following Papers and Reports were read:—

1. *On the Sense of Colour among some of the Lower Animals. By* Sir JOHN LUBBOCK, *Bart., M.P., F.R.S.*

The author began by recording some elaborate experiments made on a species of Daphnia, a small freshwater crustacean, with the spectrum. The general result was that, in opposition to the opinion of M. Paul Bert, while their limits of vision at the red end are approximately the same as ours, at the violet end they perceive light which produces no impression on our eyes.

He then proceeded to explain some experiments he had made with bees, in order to determine whether, and if so how, they are affected by different colours.

The consideration of the causes which have led to the structure and colouring of flowers is, he said, one of the most fascinating parts of natural history. Most botanists are now agreed that insects, especially bees, have played a very important part in the development of flowers.

While in many plants, almost invariably with inconspicuous blossoms, the pollen is carried from flower to flower by the wind, in the case of almost all large and brightly coloured flowers this is effected by the agency of insects. In such flowers the colours, scent, and honey serve to attract insects, while the size and form are arranged in such a manner that the insects fertilise them with pollen brought from another plant.

Nevertheless these views have not escaped criticism. M. Bonnier, for instance, has attempted to show that they are in many respects untenable.

The author does not propose on the present occasion to follow his general argument, but merely that portion of it relating to colour.

In order to test whether and how bees are affected by different colours, he tried the following experiment. He took slips of glass of the size generally used for slides for the microscope, viz. 3 inches by 1, and pasted on them slips of paper coloured respectively blue, green, orange, red, white, and yellow. He then put them on a lawn in a row about a foot apart, and on each put a second slip of glass with a drop of honey. He also put with them a slip of plain glass with a similar drop of honey. He had previously trained a bee to come to the spot for honey. His plan then was, when the bee returned and had sipped about a quarter of a minute, to remove the honey, when she flew to another slip. This then he took away, when she went to a third, and so on. In this way he induced her to visit all the drops of honey successively. When she had returned to the nest, he transposed all the upper glasses with the honey, and also moved the coloured glasses. Thus, as the drop of honey was changed each time and also the position of the glasses, neither of these could influence the selection by the bee.

In recording the results he marked down successively the order in which the bee went to the different coloured glasses. For instance, in the first journey from the nest, the bee lit first on the blue, which accordingly he marked 1; when disturbed from the blue, she flew about a little and then lit on the white; when the white was removed, she settled on the green; and so successively on the orange, yellow, plain, and red. He repeated the experiment 100 times; using two different hives, and spreading the observations over some time, so as to experiment with different bees, and under varied circumstances.

The precautions taken seem to him to have placed the different colours on an equal footing; while the number of experiments appears sufficient to give a fair average.

He may observe also that the different series agree well among themselves. The difference between the numbers is certainly striking. Adding together 1, 2, 3, 4, 5, 6, and 7 we get 28 as the total number given by each journey: 100 journeys, therefore, give, as the table shows, a total of 2,800, which divided by 7, would of course, if no preference were shown, give 400 for each colour. The numbers, however, are, for the blue, only 275; for the white, 349; yellow, 405; red, 413; green, 427; orange, 440; and plain glass as many as 491.

A second mode of testing the result is to take the percentage in which the bees went respectively to each colour, first, second, third, and so on The result is shown in another table. The result was that out of a hundred rounds the bees took blue as one of the first three in 74 cases, and one of the last four only in 26 cases; while, on the contrary, they selected the plain as one of the first three only in 25 cases, and one of the last four in 75 cases.

On the whole, then, it seems clear that bees are affected by colour, and that their favourite colour is blue.

The author ended by some remarks on the comparative paucity of blue flowers, and expressed the opinion that almost all, if not all, blue flowers had once been yellow or white.

---

2. *Report of the Committee on the Zoological Station at Naples.*—See Reports, p. 178.

---

3. *Report of the Committee on the Scottish Zoological Station.*—See Reports, p. 177.

---

4. *On our present Knowledge of the Fauna inhabiting British India and its Dependencies. By* W. T. BLANFORD, *F.R.S.*

The author called attention to the need for works on the geology, botany, and zoology of British India and its dependencies, especially as regards the second and third. These are needed, not only for students at home, but for purposes of instruction in the Indian Colleges; for if the fauna of India is ever to be thoroughly known, this result can only be obtained by enlisting the services of a large body of observers; and it is in every way desirable that many of these observers should be natives of the country. But at present the difficulties in the way of natives becoming acquainted with the animals of India are almost insuperable, and the ignorance that prevails is what might be expected.

Judging from past experience, we may wait an indefinite period before the necessary series of hand-books will be brought out by private enterprise unassisted by Government support.

Up to the present time, excluding books relating only to Ceylon or to isolated parts of the British possessions in India, only six works have been published that can be considered useful text-books for the determination of the Indian fauna. These books, with their size and date of publication, are the following:—

Günther's 'Reptiles of British India,' 1 vol. large 4to, 1864.

Jerdon's 'Birds of India,' 3 vols. large 8vo, 1862–64.

Jerdon's 'Mammals of India,' 1 vol. large 8vo. 1867.

Hanley and Theobald's 'Conchologia Indica' (plates of land and freshwater shells only), 1 vol. 4to, 1870–76.

Theobald's 'Reptiles of British India,' 1 vol. large 8vo, 1876.

Day's 'Fishes of India,' 1 vol. text, 1 vol. plates, 4to, 1875–78.

With the exception of the last-named, all of these works are now inadequate, either on account of the large additions that have been made to the subjects since they were published, or from original want of completeness.

The most successful and, in many respects, the best of the text-books named is Jerdon's 'Birds of India;' and it is not too much to say that since the appearance of that work, and, to a very great extent, in consequence of its publication, the knowledge of the subject has been quadrupled, and the number of observers and students has increased in even a larger proportion.

From experience it appears that the books most required are works very similar to those of Jerdon already quoted. There is no occasion for very detailed dissertations on habits, distribution, &c., although a condensed account is necessary, together with sufficient references to enable a student to consult other works on the subject. Of each species a brief synonymy with the more important references, a concise description, and a sufficient account of variation, habits, and distribution should be given, enough to enable a fairly intelligent observer to identify each species and to learn the principal facts in its history, and to assist those who wish for further information in consulting the literature of the subject. Synopses or keys for the determination of families, genera, and species are desirable, and illustrations of structure and occasionally of whole animals would be very important additions. The best illustrations would perhaps be furnished by woodcuts in the text. The best size for volumes is from 400 to 600 pages. Books are far better printed in England, and quite as cheaply as in India, whilst all illustrations are much better and more cheaply executed in the former country.

It is very difficult to ascertain what is the number of Invertebrata known to occur in India. The vertebrate species can be enumerated with a nearer approach to accuracy. No attempt has been made to determine the marine Invertebrata. Taking the 'red line' as a limit, and including protected and tributary States such as Baluchistan, Cashmere and its dependencies, and Nepaul, and adding Ceylon, the Andaman and Nicobar Islands, the following is an approximation to the number of species hitherto described in the various classes and orders named, only terrestrial and fluviatile Invertebrata being included. A considerable amount of time has been devoted to these lists, but it is to be feared that, in the case of the Invertebrata, they are very imperfect. Those marked with a note of interrogation are, indeed, little more than guesses.

VERTEBRATA.

	Number of species	
Mammals	390	
Birds	1650	
Reptiles	500	
Amphibia	100	
Fish	1350	
	3990	

MOLLUSCA (Land and Freshwater only).

Gasteropoda	900	
Lamellibranchiata	100	
	1000	

ARTHROPODA.

Insecta.		
Coleoptera	4780	
Hymenoptera	850	
Lepidoptera	4620	
Diptera	500 ?	
Rhynchota	650	
Neuroptera	350	
Orthoptera	350 ?	
		12,100
Myriopoda	50 ?	
Arachnida	120	
Crustacea	100 ?	
		270
		12,370

Vermes.

Only about 14 species appear to be recorded; these are Planarians, earthworms, and leeches.

A list like the above scarcely needs comment. To suppose that in a country from which between 4,000 and 5,000 species of Lepidoptera have been described there are not 1,000 Hymenoptera, less than 5,000 Coleoptera, and, above all, scarcely more than 100 spiders, is absurd. It is evident that our knowledge of the Invertebrates of India is of the most rudimentary and imperfect description.

---

5. *On a Fossil Stem from the Halifax Coal-measures.* *By* Thomas Hick, *B.A., B.Sc., and* William Cash, *F.G.S.*

The stem described is one that has been obtained by Mr. James Binns from the Lower Coal-measures of Halifax, Yorkshire. Though somewhat flattened on one side and imperfect on the other, it is sufficiently well-preserved to indicate that it was originally cylindrical in its general form. It consists of a central pith, surrounded by a number of slightly wedge-shaped masses of vascular or fibro-vascular tissue. Outside these masses of tissue, or bundles as they may be called, is a cambium zone, followed by a comparatively thick cortex. Its whole diameter is ·147 of an inch.

The pith has a parenchymatous structure quite similar to that met with in recent herbaceous stems and in the youngest shoots of woody perennials.

The vascular tissue surrounds the pith in a narrow zone, and in the transverse section bears a remarkable resemblance to the Xylem portions of the fibro-vascular bundles of dicotyledons during the first season of growth. It is composed chiefly of vessels of the barred and dotted types.

The pith and vascular tissue combined form a central cylindrical axis to the stem, which has a diameter of ·056 of an inch.

The cambium layer lies outside the vascular zone, and consists of delicate thin-walled cells, which again remind us of young dicotyledonous stems and branchlets. It is not, however, separated from the cortex by the interposition of any elements having the appearance of phloëm.

The cortex is the most characteristic portion of the stem, and differs from anything previously met with in the stems of fossil plants. It is of considerable thickness compared with the diameter of the central axis, and is, apparently, entirely cellular. In the middle portion there is a series of large air-spaces, which run through the stem in a longitudinal direction, and which are destitute of tissue of any kind. These are separated from one another by thin plates of tissue, one cell thick, which run in a radial direction from the central axis to the periphery. In the possession of these air-spaces, and the histological structure of the parenchyma that separates them, the fossil agrees very closely with such well-known aquatic genera as *Myriophyllum*, *Hippuris*, *Hottonia*, *Potamogeton*. With the stem of *Myriophyllum*, indeed, it is almost identical, the radiating plates of parenchyma met with in the cortex, exhibiting the same arrangement in both cases, and being destitute of the numerous anastomoses which are met with in the other genera. The chief difference between them is in the vascular axis. In the fossil, this shows the distinction of pith and vascular bundles above-mentioned, but exhibits no trace of a fibro-vascular bundle-sheath. In *Myriophyllum* the axis is composed of a thin-walled cambiform tissue, intermixed with which, in a more or less irregular manner, are a few spiral vessels, and the whole is enclosed in a well-defined fibro-vascular bundle-sheath. Though attaching great weight to these differences, the authors do not regard them as absolutely decisive against the affinity of the fossil plant with *Myriophyllum*. They consider it probable that *Myriophyllum* and the other genera referred to are the existing representatives of plants that were formerly more abundant, and whose tissues were more highly differentiated, and which therefore might have had a vascular axis of the character seen in the fossil under description.

They propose to designate their specimen *Myriophylloides Williamsoni*, in honour of Professor W. C. Williamson, F.R.S.

---

6. *Notes on Chlamydomyxa.* *By* P. A. Geddes.

---

7. *On a New Sub-Class of Infusorians.* *By* P. A. Geddes.

---

8. *On the Improvement of Freshwater Fisheries.* *By* Lieut.-General Sir James E. Alexander, *Knt., C.B., F.R.S.E.*

Endeavours have been made for several years to induce attention to be directed to the pollution of rivers in Scotland, and the loss of valuble breeding-grounds for salmon. The Duke of Buccleugh, the Marquis of Lothian, Sir Robert Christison, Mr. Milne Home, and others co-operated, and the Scotch Fisheries Improvement Association was instituted. Owing to the extensive manufactures it is difficult to prevent the pollution of streams. Settling and filtering ponds should be established, such as there are at Blanefield Works, at Hawick, &c. Bad state of the Devon from impurities. Mr. Young, Commissioner of Scotch Salmon Fisheries, recommended a close time, the removal of obstructions in rivers, fixed engines in river-mouths and estuaries, reformation of district boards, and the prevention of poaching. Mr. Frank Buckland alluded to the confusing salmon legislation, and recommended a single Act. Stake nets should be abolished near the mouths of rivers. The author describes how the salmon are intercepted on the caulds or weirs of the Tweed. He approves of the mode of keeping the Teith clear at the Deanstone works, no sewage being allowed to enter the river. Old fishers state that salmon live on their own substance in fresh water; this is disputed. The paper notices Sir James Maitland, a great hatcher, and the fungoid disease in the Tweed.

---

9. *On some Vestiges of the Ancient Forest of part of the Pennine Chain.*[1] *By* Joseph Lucas.

Nidderdale and its moors have formerly been covered by an extensive forest. Many trees lie buried in the peat upon the moors, but the birch appears almost everywhere predominant. Hazel, sealh (willow), thorn, oaks, &c., also occur, but at a certain elevation above 1,000 feet the birch must have formed an almost universal forest by itself, such as may be seen on the west coast of Norway at the present day.

The upper parts of the Moorland Gills, and much of what is now the moors, must formerly have made a beautiful appearance, with its light gauze-like forest of birch and mountain-ash. The last surviving example on any considerable scale is preserved in Birk Gill, a tributary of the river Burn. There is no cultivation in the gill, the bottom of which is 600 feet above sea at its mouth, the gill being 400 feet deep and half a mile wide from ridge to ridge. The belt of wood clothes the sides for 200 feet, or up to 800 feet at its mouth, and ends where the bed of the stream reaches 900 feet, in a distance of rather over a mile. The wood consists of mountain-ash, ash, alder, oak, birch, holly, and thorn, and above 900 feet, the following stragglers were noted:—Highest living.—M.-ash, 900; alder, 950; salix, 970; birch, 975; holly, highest living tree, 1,000. In *Scale Gill*, thorn, 1,100; M.-ash, 1,175. In *Barnley Beck*, salix, 1,050; thorn, 1,080; birch, 1,125; holly, 1,150; M.-ash 1,150. In *Colsterdale*, *House Gill*, M.-ash, 1,150. *New House Gill*,

[1] The subject of the above abstract will be found treated at length in the author's *Studies in Nidderdale*, xiii. and xiv. pp. 107–120. (Thorpe, Pateley Bridge.)

M.-ash, 1,175. *Main Valley of River Burn,* thorn 1,175. In *Long Gill,* birch, 1,175; M.-ash, 1,250. *Bakstone Gill,* M.-ash, 1,275. *Steel House Gill,* M.-ash and bullace, 1,375. *River Burn,* M.-ash, 1,225. *Thorny Grane,* M.-ash, 1,200. *Deep Gill,* M.-ash, 1,255. The above indicate the highest living tree of any kind in each case.

Woo Gill, hazel, 1,350; birch, 1,275; salix, 1,375; M.-ash, 1,550.

Now let us compare the above heights with the elevations at which their remains are found buried in the peat.

Thus the *highest living* Birches are in Long Gill, 1,175, Barnley Beck, 1,125, and High Scar Backstone Gill, Nidderdale, 1,100. But birch-stems are found in the peat up to 1,725 feet, and doubtless higher. The highest living Hazel is in Woo Gill, 1,350 feet, but there was a time when the hazel not only grew but ripened its nuts at 1,650 feet, on the moor east of Henstone Band at the head of Gate-up Gill. Here I found buried in the peat hazel-nuts, many of which were bored by a maggot, proving that the nut came to maturity, and the kernel was eaten out by the worm.

The highest living oaks are two in High Scar, Bakstone Gill, 1,100, and Fox Crag ditto, one oak, 950. Birk Gill, 900. These are solitary instances, and are all very small; but there are many oaks in the peat between Blagshaw Gill and Brown Rigg, 1,000 to 1,250 feet in Nidderdale.

From the remains of the lost forest we can distinguish two zones: that of oaks up to about 1,200 feet, and that of birches above that level.

Of the valley proper, the birch and thorn covered the upper part of the sides of the dale, or the 'edge,' while in the bottom there flourished sycamore, ash, holly, hazel, alder, wych elm, and near the dale-head the heckberry (bird cherry), as proved by their remains found on the scars, &c.

The peat, which overwhelmed the ancient forests, is not now forming, but on the whole is now undergoing a process of destruction. Except in the 'whams' (swamps), the conditions for its formation do not exist. In summer, on the higher ranges, the peat becomes very dry and dust-like, when it is swept away by the strong winds. Near Great Whernside acres together of bare rock have been thus denuded.

The peat on these moors does not run to a great thickness—about 6 to 8 feet is the general observation—a fact which reduces our conception of the length of time required for its formation, and gives some colour to my interpretation of the words 'shaw' and 'with,' occurring on these moors.

With (O.-Norsk. *Vidr,* a wood) does not occur in Nidderdale above Hartwith, but in Washburndale '*Blaywith* Wham' (O.-N. *Hvammr,* a swamp), is over 1,000 feet on the open moors. *Blay* means *bleak,* so the Blaywith Wham would thus mean '*Bleak Wood Swamp.*' There are no trees there now, and there are none at Grimwith. This raises the curious question, Were there trees there since the Danes settled in this part? Some light may be thrown upon the answer by the parallel case of 'Shaw,' a wood (O.-N. *Skógr*), a word apparently exclusively Danish in this sense as it is common in Jutish Kent. (O.-N. *Skógr.* Swed. *Skog,* Dan. *Skov,* a wood.) The analogous words A.-S. *Scúa* O.-N. *Skuggi* Dut. *Schawe* mean *shade, shelter.*

Shaw, meaning wood, is common in the ballads and Chaucer, as in the beautiful lines in 'Robin Hood'—

> 'In somer when the shawes be sheen,
> And leves be large and lang.'

It is therefore interesting to note that 'shaw' occurs many times on the open moors, far above the present limits of tree-vegetation. In such positions 'shaw' is now generally a boggy or rocky place associated with wet ground.

There are no trees or bushes in Shaw Gill, 1,200 to 1,580 feet, or Shaw Gill Sike 1,150 to 1,400 on Feather Shaw, 1,250, West Shaw, 1,200, Foulshaw Crags, 1,000, or on Shawsridge near Greenhow Hill. I cannot doubt that trees of some kind gave the name to all these places when the Danes took possession of them 1,000 years ago.

---

10. *Report on the Marine Fauna of the Southern Coast of Devon and Cornwall.*—See Reports, p. 198.

DEPARTMENT OF ANTHROPOLOGY.

Chairman of the Department—Professor W. H. Flower, LL.D., F.R.S., F.R.C.S., F.L.S., F.G.S., Pres. Z.S. (Vice-President of the Section).

THURSDAY, SEPTEMBER 1.

The Chairman delivered the following Address:—

It is impossible for us to commence the work of this Section of the Association without having vividly brought to our minds the loss which has befallen us since our last meeting—the loss of one who was our most characteristic representative of the complex science of Anthropology—one who had for many years conducted with extraordinary energy, amidst multifarious other avocations, a series of researches into the history, customs, and physical characters of the early inhabitants of our island, for which he was so especially fitted by his archæological, historical, and literary as well as his anatomical knowledge, and who was also the most popular and brilliant expositor, to assemblies such as meet together on these occasions, of the results of those researches. I need scarcely say that I refer to Professor Rolleston.

Within the last few months the study of our subject in this country has received an impulse from the publication of a book—small in size, it is true, but full of materials for thought and instruction—the 'Anthropology' of Mr. E. B. Tylor, the first work published in English with that title, and one very different in its scope and method from the older ethnological treatises.

The immense array of facts brought together in a small compass, the terseness and elegance of the style, the good taste and feeling with which difficult and often burning questions are treated, should give this book a wide circulation among all classes, and thoroughly familiarise both the word and the subject to English readers.

The origin and early history of man's civilisation, his language, his arts of life, his religion, science, and social customs in the primitive conditions of society, are subjects in which, in consequence of their direct continuity with the arts and sciences, religious, political, and social customs among which we all live, by which we are all influenced, and about which we all have opinions, every person of ordinary education can and should take an interest. In fact, really to understand all these problems in the complex condition in which they are presented to us now, we ought to study them in their more simple forms, and trace them as far as may be to their origins.

But, as the author remarks, this book is only an introduction to anthropology, rather than a summary of all that it teaches; and some, even those that many consider the most important, branches of the subject are but lightly touched upon, or wholly passed over.

In one of the estimates of the character and opinions of the very remarkable man and eminent statesman, whose death the country was mourning last spring, it was stated: 'Lord Beaconsfield had a deep-rooted conviction of the vast importance of race, as determining the relative dominance both of societies and of individuals;'[1] and with regard to the question of what he meant by 'race,' we have a key in the last published work of the same acute observer of mankind: 'Language and religion do not make a race—there is only one thing which makes a race, and that is blood.'[2] Now 'blood' used in this sense is defined as 'kindred; relation by natural descent from a common ancestor; consanguinity.'[3] The study of the true

[1] *Spectator*, April 23, 1881. [2] *Endymion*, vol. ii. p. 205.
[3] Webster's *Dictionary*.

relationship of the different races of men is then not only interesting from a scientific point of view, but of great importance to statesmanship in such a country as this, embracing subjects representing almost every known modification of the human species whose varied and often conflicting interests have to be regulated and provided for. It is to want of appreciation of its importance that many of the inconsistencies and shortcomings of the government of our dependencies and colonies are due, especially the great inconsistency between a favourite English theory and a too common English practice—the former being that all men are morally and intellectually alike, the latter being that all are equally inferior to himself in all respects: both propositions egregiously fallacious. The study of race is at a low ebb indeed when we hear the same contemptuous epithet of 'nigger' applied indiscriminately by the Englishman abroad to the blacks of the West Coast of Africa, the Kaffirs of Natal, the Lascars of Bombay, the Hindoos of Calcutta, the aborigines of Australia, and even the Maoris of New Zealand!

But how is he to know better? Where in this country is any instruction to be had? Where are the books to which he may turn for trustworthy information? The subject, as I have said, is but slightly touched upon in the last published treatise on anthropology in our language. The great work of Pritchard, a compendium of all that was known at the time it was written, is now almost entirely out of date. In not a single university or public institution throughout the three kingdoms is there any kind of systematic teaching, either of physical or of any other branch of anthropology, except so far as comparative philology may be considered as bearing upon the subject. The one society of which it is the special business to promote the study of these questions, the Anthropological Institute of Great Britain and Ireland, is, I regret to say, far from flourishing. An anthropological museum, in the proper sense of the word, either public or private, does not exist in this country.

What a contrast is this to what we see in almost every other nation in Europe! At Paris there is, first, the Museum d'Histoire Naturelle, where man, as a zoological subject—almost entirely neglected in our British Museum—has a magnificent gallery allotted to him, abounding not only in illustrations of osteology, but also in models, casts, drawings, and anatomical preparations showing various points in his physical or natural history, which is expounded to the public in the free lectures of the venerable Professor Quatrefages and his able coadjutor, Dr. Hamy; there is also the vigorous Society of Anthropology, which is stated in the last annual report to number 720 members, showing an increase of 44 during the year 1880, and which is forming a museum on a most extensive scale; and, finally, the School of Anthropology, founded by the illustrious Broca, whose untimely death last year, instead of paralysing, seems to have stimulated the energies of colleagues and pupils into increased activity. In this school, supported partly by private subscriptions, partly by the public liberality of the Municipality of Paris, and of the Department of the Seine, are laboratories in which all the processes of anthropological manipulation are practised by students and taught to travellers. Here all the bodies of persons of outlandish nationalities dying in any of the hospitals of Paris are dissected by competent and zealous observers, who carefully record every peculiarity of structure discovered, and are thus laying the foundation for an exhaustive and trustworthy collection of materials for the comparative anatomy of the races of man. Here, furthermore, are lectureships on all the different branches. Biological and anatomical anthropology, ethnology, pre-historic, linguistic, social, and medical anthropology are all treated of separately by eminent professors who have made these departments their special study. The influence of so much activity is spreading beyond the capital. The foundation of an Anthropological Society at Lyons has been announced within the present year.

In Germany, although there is not at present any institution organised like the school at Paris, the flourishing state of the Berlin Ethnological Society, which also reports a large increase in the number of its members, the various other societies and journals, and the important contributions which are continually being made from the numerous intellectual centres of that land of learning, all attest the interest which the study of man excites there. In Italy, in the Scandinavian kingdoms, in Russia, and even in Spain, there are signs of similar activity. A glance at the recent periodical literature of America, especially the publications of the Smithsonian Institution, will show how strongly the scientific work of that country is setting in the same direction.

It is true that a very great proportion of the energies of the societies, institutions, and individuals who cultivate this vast subject are, in all these lands, as it is indeed to so great an extent in our own, devoted to that branch which borders upon the old and favourite studies of archæology and geology. The fascinating power of the pursuit of the earliest traces of man's existence upon the earth, with the possibilities of obtaining some glimpses of his mode of origin, is attested in the devotion seen everywhere in museums, in separate publications, and in journals, to pre-historic anthropology.

But, though the study of man's origin and earliest appearances upon the earth, and that of the structural modifications to which in course of time he has arrived, or the study of races, are intimately related, and will ultimately throw light upon one another, I venture to think that the latter is the more pressing of the two, as it is certainly the more practically important; and hence the necessity for greater attention to physical anthropology. In seeking for a criterion upon which to base our study of races, in looking for essential proofs of consanguinity of descent from common ancestors in different groups of men, I have no hesitation in saying that we must first look to their physical or anatomical characters, next to their moral and intellectual characters—for our purpose more difficult of apprehension and comparison—and, lastly, as affording hints, often valuable in aid of our researches, but rarely to be depended upon, unless corroborated from other sources, to language, religion, and social customs.

The study of the physical or anatomical character of the races of man is unfortunately a subject beset with innumerable difficulties. It can only be approached with full advantage by one already acquainted with the ordinary facts of human anatomy, and with a certain amount of zoological training. The methods used by the zoologist in discriminating species and varieties of animals, and the practice acquired in detecting minute resemblances and differences that an ordinary observer might overlook, are just what are required in the physical anthropologist.

As the great problem which is at the root of all zoology is to discover a natural classification of animals, so the aim of zoological anthropology is to discover a natural classification of man. A natural classification is an expression of our knowledge of real relationship, of consanguinity—of 'blood,' as the author of 'Endymion' expresses it. When we can satisfactorily prove that any two of the known groups of mankind are descended from the same common stock, a point is gained. The more such points we have acquired, the more nearly shall we be able to picture to ourselves, not only the present, but the past distribution of the races of man upon the earth, and the mode and order in which they have been derived from one another.

The difficulties in the way of applying zoological principles to the classification of man are vastly greater than in the case of most animals; the problem being, as we shall see, one of much greater complexity. When groups of animals become so far differentiated from each other as to represent separate species, they remain isolated; they may break up into further subdivisions—in fact, it is only by further subdivision that new species can be formed; but it is of the very essence of species, as now universally understood by naturalists, that they cannot recombine, and so give rise to new forms. With the varieties of man it is otherwise. They have never so far separated as to answer to the physiological definition of species. All races are fertile one with another, though perhaps in different degrees. Hence new varieties have constantly been formed, not only by the segmentation, as it were, of a portion of one of the old stocks, but also by various combinations of those already established.

Neither of the old conceptions of the history of man, which pervaded the thought, and form the foundation of the works of all ethnological writers up to the last few years, rest on any solid basis, or account for the phenomena of the present condition and distribution of the species.

The one view—that of the monogenist—was that all races, as we see them now, are the descendants of a single pair, who, in a comparatively short period of time, spread over the world from one common centre of origin, and became modified by degrees in consequence of changes of climate and other external conditions. The other—that of the polygenist—is that a certain number of varieties or species (no agreement has been arrived at as to the number, which is estimated by different authorities at from three to twenty or more) have been independently created in different parts of the world, and have perpetuated the distinctive characters as well as the geographical position with which they were originally endowed.

The view which appears best to accord with what is now known of the characters and distribution of the races of man, and with the general phenomena of nature, may be described as a modification of the former of these hypotheses.

Without entering into the difficult question of the method of man's first appearance upon the world, we must assume for it a vast antiquity—at all events as measured by any historical standard. Of this there is now ample proof. During the long time he existed in the savage state—a time compared to which the dawn of our historical period was as yesterday—he was influenced by the operation of those natural laws which have produced the variations seen in other regions of organic nature. The first men may very probably have been all alike; but, when spread over the face of the earth, and become subject to all kinds of diverse external conditions—climate, food, competition with members of his own species or with wild animals—racial differences began slowly to be developed through the potency of various kinds of selection acting upon the slight variations which appeared in individuals in obedience to the tendency implanted in all living things.

Geographical position must have been one of the main elements in determining the formation and the permanence of races. Groups of men isolated from their fellows for long periods, such as those living on small islands, to which their ancestors may have been accidentally drifted, would naturally, in course of time, develop a new type of features, of skull, of complexion or hair. A slight set in one direction, in any of these characters, would constantly tend to intensify itself, and so new races would be formed. In the same way different intellectual or moral qualities would be gradually developed and transmitted in different groups of men. The longer a race thus formed remained isolated, the more strongly impressed and the more permanent would its characteristics become, and less liable to be changed or lost, when the surrounding circumstances were altered, or under a moderate amount of intermixture from other races—the more 'true,' in fact, would it be. On the other hand, on large continental tracts, where no 'mountains interposed make enemies of nations,' or other natural barriers form obstacles to free intercourse between tribe and tribe, there would always be a tendency towards uniformity, from the amalgamation of races brought into close relation by war or by commerce. Smaller or feebler races have been destroyed or absorbed by others impelled by superabundant population or other causes to spread beyond their original limits; or sometimes the conquering race has itself disappeared by absorption into the conquered.

Thus, for untold ages, the history of man has presented a shifting kaleidoscopic scene; new races gradually becoming differentiated out of the old elements, and, after dwelling awhile upon the earth, either becoming suddenly annihilated or gradually merged into new combinations; a constant destruction and reconstruction; a constant tendency to separation and differentiation, and a tendency to combine again into a common uniformity—the two tendencies acting against and modifying each other. The history of these processes in former times, except in so far as they may be inferred from the present state of things, is a difficult study, owing to the scarcity of evidence. If we had any approach to a complete palæontological record, the history of man could be reconstructed; but nothing of the kind is forthcoming. Evidences of the anatomical characters of man, as he lived on the earth during the time when the great racial characteristics were being developed, during the long ante-historic period in which the negro, the Mongolian, and the Caucasian were being gradually fashioned into their respective types, is entirely wanting, or, if any exists, it is at present safely buried in the earth, perhaps to be revealed at some unexpected time, and in some unforeseen manner.

It will be observed, and perhaps observed with perplexity by some, that no definition has as yet been given of the oft-recurring word 'race.' The sketch just drawn of the past history of man must be sufficient to show that any theory implying that the different individuals composing the human species can be parcelled out into certain definite groups, each with its well-marked and permanent limits separating it from all others, has no scientific foundation; but that, in reality, these individuals are aggregated into a number of groups of very different value in a zoological sense, with characters more or less strongly marked and permanent, and often passing insensibly into one another. The great groups are split up into minor subdivisions, and filling up the gaps between them all are intermediate or intercalary forms, derived either from the survival of individuals retaining the generalised or ancestral characters of a race from which two branches have separated and taken opposite lines of modification, or from the reunion of members of such branches in recent times. If we could follow those authors who can classify mankind into such divisions as trunks, branches, races and sub-races, each having its definite and equivalent meaning, our work would appear to be greatly simplified, although perhaps we should not be so near the truth we are seeking. But being not yet in a position to define what amount of modification is necessary to constitute distinction of race, I am compelled to use the word vaguely for any considerable group of men who resemble each other in certain common characters transmitted from generation to generation.

In approaching the question of the classification of the races of man from a physical point of view, we must bestow great care upon the characters upon which we rely in distinguishing one group from another. It is well known in zoology that the modifications of a single organ or system may be of great value, or may be quite useless according as such modifications are correlated with others in different organs or systems, or are mere isolated examples of variation in the economy of the animal without structural changes elsewhere. The older ornithologists associated in one order all the birds with webbed feet, and the order thus constituted, *Natatores* or *Palmipedes*, which received the great sanction of Cuvier, still stands in many zoological compilations. Recent investigations into the anatomy of birds have shown that the species thus associated together show no other sign of natural affinity, and no evidence of being derived from the same stock. In fact, there is tolerably good proof that the webbing of the feet is a merely adaptive character, developed or lost, present or absent, irrespective of other structural modifications. In the same way, when anthropology was less advanced than it is now, it was thought that the distinction between long and short-headed, dolichocephalic and brachycephalic people, pointed out by Retzius, indicated a primary division of the human species; but it was afterwards discovered that, although the character was useful otherwise, it was one of only secondary importance, as the long-headed as well as the short-headed group both included races otherwise of the strongest dissimilarity.

In all classifications, the point to be first ascertained is the fundamental plan of construction; but in cases where the fundamental plan has undergone but little modification, we are obliged to make use of what appear trivial characters, and compensate for their triviality by their number. The more numerous the combinations of specialised characters, by which any species or race differs from its congeners, the more confidence we have in their importance. The separation of what is essential from what is incidental or merely superficial in such characters lies at the root of all the problems of this nature that zoologists are called upon to solve; and in proportion as the difficulties involved in this delicate and often perplexing discrimination are successfully met and overcome will the value of the conclusions be increased. These difficulties, so familiar in zoology, are still greater in the case of anthropology. The differences we have to deal with are often very slight; their significance is at present very little understood. We go on expending time and trouble in heaping up elaborate tables of measurements, and minutely recording every point that is capable of description, with little regard to any conclusions that may be drawn from them. It is certainly time now to endeavour, if possible, to discriminate characters which indicate deep-lying affinity from those that are more transient, variable or adaptive, and to adjust, as far as may be, the proper importance to be attached to each.

It is, however, quite to be expected that, in the infancy of all sciences, a vast amount of labour must be expended in learning the methods of investigation. In none has this been more conspicuous than in the subject under consideration. Many have come to despair, for instance, of any good, commensurate with the time it occupies, coming of the minute and laborious work involved in craniometry. This is because nearly all our present methods are tentative. We have not yet learnt, or are only beginning to learn, what lines of investigation are profitable and what are barren. The results, even as far as we have gone, are, however, quite sufficient, in my opinion, to justify perseverance. I am, however, not so sure whether it be yet time to answer the demand, so eager and so natural, which is being made in many quarters for the formulation of a definite plan of examination, measurement, and description to which all future investigation should rigidly adhere. All steps to promote agreement upon fundamental points are to be cordially welcomed, and meetings or congresses convened for such a purpose will be of use by giving opportunities for the impartial discussion of the relative value of different methods; but the agreement will finally be brought about by the general adoption of those measurements and methods which experience proves to be the most useful, while others will gradually fall into disuse by a kind of process of natural selection.

The changes and improvements which are being made yearly, almost monthly, in instruments and in methods, show what we should lose if we were to stop at any given period, and decree in solemn conclave that this shall be our final system, this instrument and this method shall be the only one used throughout the world, that no one shall depart from it. We scarcely need to ask how long such an agreement would be binding. The subject is not sufficiently advanced to be reduced to a state of stagnation such as this would bring it to.

To take an example from what is perhaps the most important of the anatomical characters by which man is distinguished from the lower animals, the superior from the inferior races of man: the smaller or greater projection forwards of the lower part of the face in relation to the skull proper, or that which contains the brain. From the time when Camper drew his facial angle, to the present day, the readiest and truest method of estimating this projection has occupied the attention of anatomists and anthropologists, and we are still far from any general agreement. Every country, every school, has its own system, so different that comparison with one another is well-nigh impossible. This is undoubtedly an evil; but the question is whether we should all agree to adopt one of the confessedly defective systems now in vogue, or whether we should not rather continue to hope for, and endeavour to find, one which may not be subject to the well-known objections urged against all.

We want, especially in this country, more workers, trained and experienced men who will take up the subject seriously, and devote themselves to it continuously. Of such we may say, without offence to those few who have done occasional excellent work in physical anthropology, but whose chief scientific activity lies in other fields, we have not one. In the last number of the French *Revue d'Anthropologie*, a reference caught my eye to a craniometrical method in use by the 'English school' of anthropologists. It was a reference only to a method which I had ventured to suggest, but which, as far as I know, has not been adopted by anyone else. A school is just what we have not, and what we want—a body of men, not only willing to learn, but able to discuss, to criticise, to give their approval to, or reduce to its proper level, the results put forth by our few original investigators and writers. The rapidity with which anyone of the most slender pretensions who ventures into the field (I speak from painful experience) is raised to be an oracle among his fellows is one of the most alarming proofs of the present barrenness of the land.

Another most urgent need is the collection and preservation of the evidences of the physical structure of the various modifications of man upon the earth. Especially urgent is this now, as we live in an age in which, in a far greater degree than any previous one, the destruction of races, both by annihilation and absorption, is going on. The world has never witnessed such changes in its ethnology as those now taking place, owing to the rapid extension of maritime discovery and maritime commerce, which is especially affecting the island population among which, more than elsewhere, the solution of the most important anthropological problems may be looked for. If we have at present neither the knowledge nor the leisure to examine and describe, we can at least preserve from destruction the materials for our successors to work upon. Photographs, models, anatomical specimens, skeletons or parts of skeletons, with their histories carefully registered, of any of the so-called aboriginal races, now rapidly undergoing extermination or degeneration, will be hereafter of inestimable value. Drawings, descriptions, and measurements are also useful, though in a far less degree, as allowance must always be made for imperfections in the methods as well as the capacity of the artist or observer. Such collections must be made upon a far larger scale than has hitherto been attempted, as, owing to the difficulties already pointed out in the classification of man, it is only by large numbers that the errors arising from individual peculiarities or accidental admixture can be obviated, and the prevailing characteristics of a race or group truly ascertained. It is only in an institution commanding the resources of the nation that such a collection can be formed, and it may therefore be confidently hoped that the trustees of the British Museum will appropriate some portion of the magnificent new building, which has been provided for the accommodation of their natural history collections, to this hitherto neglected branch of the subject.

I have mentioned two of the needs of anthropology in this country—more workers and better collections: there is still a third—that of a society or institution in which anthropologists can meet and discuss their respective views, with a journal in which the results of their investigations can be laid before the public, and a library in which they can find the books and periodicals necessary for their study. All this ought to be provided by the Anthropological Institute of Great Britain and Ireland, which originated in the amalgamation of the old Ethnological and Anthropological Societies. But, as I intimated some time ago, the Institute does not at the present time flourish as it should; its meetings are not so well attended as they might be; the journal is restricted in its powers of illustration and printing by want of funds; the library is quite insufficient for the needs of the student.

This certainly does not arise from any want of good management in the Society itself. Its affairs have been presided over and administered by some of the most eminent and able men the country has produced. Huxley, Lubbock, Busk, Evans, Tylor, and Pitt-Rivers have in succession given their energies to its service, and yet the number of its members is falling away, its usefulness is crippled, and its very existence seems precarious. Some decline to join the Institute, others leave it, upon the plea that, being unable from distance or other causes to attend the meetings, they cannot obtain the full return for their subscriptions; others on the ground that the Journal does not contain the exact information which they require.

There surely is to be found a sufficient number of persons, influenced by different considerations, who feel that anthropological science is worth cultivating, and that those who are laboriously and patiently tracing out the complex problems of man's diversity and man's early history are doing a good work, and ought to be encouraged by having the means afforded them of carrying on their investigations and of placing the results of their researches before the world—who feel, moreover, that there ought to be some central body, representing the subject, which may, on occasion, influence opinion or speak authoritatively on matters often of great practical importance to the nation.

There must be many in this great and wealthy country who feel that they are helping a good cause in joining such a society, even if they are not individually receiving what they consider a full equivalent for their small subscription—

many who feel satisfaction in helping the cause of knowledge, in helping to remove the opprobrium that the British Anthropological Society alone of those of the world is lacking in vitality, and in helping to prevent this country from falling behind all the nations in the cultivation of a science in which for the strongest reasons it might be expected to hold the foremost place. It is a far more grateful task to maintain, extend, and if need be improve, an existing organisation, than to construct a new one. I feel, therefore, no hesitation in urging upon all who take interest in the promotion of the study of Anthropology to rally round the Institute, and to support the endeavours of the present excellent President to increase its usefulness.

The following Report and Paper were read:—

1. *Report on the Exploration of the Caves of the South of Ireland.*

See Reports, p. 218.

2. *On the Stature of the Inhabitants of Hungary.* *By* Dr. Beddoe, *F.R.S.*

The paper was based mainly on the facts gotten by Kőrösi and by Scheiber, of Bucharest, from the national recruiting statistics. The writer, from Körösi's data, estimated the average stature of the fully grown Hungarian soldier at about 1,668 millimètres, or 5 feet 5⅝ inches English. There is a good deal of difference between the several races included in the returns, the Germans and Croats, for example, being taller than the Magyars and Roumanians. The citizens of Buda-pesth, Stuhlweissemburg, and Raab are taller than the neighbouring country-folks, at least Scheiber found it so at the age of twenty. Similarly Quetelet found the townsmen taller in Belgium, but in England the reverse is the case. In five western counties (including Pesth), where the population is mainly Magyar, the mean stature at 25 years may be estimated at 5 feet 5·2 inches.

FRIDAY, SEPTEMBER 2.

The following Papers were read:—

1. *The Viking's Ship, discovered at Sandefjord in Norway*, 1880.[1] *By* J. Harris Stone, *M.A., F.L.S., F.C.S.*

The writer paid several visits to the ship and carefully examined her. He also took four photographs of portions of the vessel. These, with diagrams made from them, were exhibited to the Section.

The paper professes to be nothing more than an account of the vessel, prepared after the writer's visits.

After alluding to the good state of preservation in which the vessel was found, and fixing—as near as possible—the probable date, by referring briefly to the Viking period, the writer shortly alludes to the Frithiof Saga, giving a few extracts which bear upon ships for the purpose of showing (1) the feeling of the period towards these vessels, and (2) also as explaining the careful and thorough workmanship so clearly evinced in this Sandefjord vessel.

The writer states the reason why the vessel was found in a mound, namely that a Viking was buried in her, and describes the sepulchral chamber.

The galleys depicted in the Bayeux tapestry were alluded to, and their shape compared with that of this vessel.

[1] A full account of the vessel, by the same writer, appeared in the November number of *Good Words* for 1881.

The remaining portion of the paper is occupied by a descriptive account of the vessel generally, each part separately, the loose articles which were found in the sepulchral chamber, and those which were found in the mound around the vessel.

---

2. *On Excavations in the Earthwork called Danes' Dyke at Flamborough, and on the Earthworks of the Yorkshire Wolds. By* Major-General Pitt-Rivers, *F.R.S.* (formerly Colonel Lane-Fox).

General Pitt-Rivers showed, by means of a large map, that many of the entrenchments on the Wolds and north of the Derwent Valley appeared to have formed part of a connected system for the defence of the ground from the westward. 1st. The entrenchment known as the Danes' Dyke, which cuts off Flamborough Head, was obviously an entrenchment intended to secure the promontory from an attack from the west. Next the Argam Dyke was a work parallel to the last, and probably formed the next position which the invaders took up as they advanced inland. The North Wolds are fortified by an entrenchment which runs along the top of the chalk escarpment overlooking the Derwent Valley, and several entrenchments on the North and South Wolds run along the hills in a position to command the valleys to the westward. On the oolite hills to the north of the Derwent Valley there are numerous ravines which run southward into the valley, and some of them are fortified by entrenchments on their eastern brow, which proved that the defenders of the district anticipated an attack from the west. General Pitt-Rivers made a cutting through the Danes' Dyke, to ascertain if possible the date of its construction, and in so doing found evidence of the manufacture of flint implements, both before and after the construction of the entrenchment. Close beneath the top of the rampart he found a large number of flint flakes, lying in a horizontal position just beneath the surface soil, in a position to prove that the defenders must have worked flints on the bank after it had been made. As many as 827 flakes and artificially formed chips of flint were found in this position. This result shows that the dyke was not later than the Bronze Period, that is to say, the period of the tumuli on the Wolds, which Canon Greenwell has shown to have belonged to the Early Bronze Age—an age in which flint continued to be used for many ordinary purposes. The question as to where the invaders came from, if invaders they were, was influenced by the consideration that the Early Bronze Age does not appear to have existed in Denmark, and if the invaders came from there, some isolated specimens of bronze implements analogous to those found in Denmark would certainly have been found in the Wolds, instead of the simple triangular dagger and axe-head, which is rarely found in Denmark. The idea that the dykes were made by Anglian invaders, however natural it at first sight appeared, must therefore, as the result of these diggings, be given up. The paper was illustrated by a section of the Danes' Dyke to scale, showing the positions of the objects found in it.

---

3. *On the Application of Composite Portraiture to Anthropological purposes. By* Francis Galton, *F.R.S.*

The author exhibited a composite picture of eight skulls of male Andaman Islanders. They had been successively mounted under the instruction of Mr. Flower, upon a rod passing through the occipital foramen, with the base of the skull at right angles to the rod. Each portrait represented one of the skulls in exact profile, with the light falling upon it from the same side. The separate portraits were combined into a single composite by the author's new instrument, described in the 'Photographic Journal' of last June, and exhibited in the Loan Museum during the meeting. The portraits were successively adjusted by the images of three fiducial lines. Thus the front edge of the image of the rod in each portrait was adjusted to a vertical line, and the base of the condyle to a horizontal one, in order to regulate the position of the skull, and the point of intersection of the roof of the skull with the vertical line was made to accord with a second horizontal line, in order to get uniformity of scale. The author referred to numerous composites illustrating the physiognomy of disease, made by himself and Dr. Mahomed, which were exhibited in the Loan Collection, as testifying to the applicability of the process to various anthropological purposes, including the pictorial definition of races. With the aid of the new instrument composites could be made by him much more exactly and easily than had been possible before. The process produces true anthropological averages. It gives an average face by a single set of operations, between the features of which any number of cross measurements can be made. It deals with averages of shading that can hardly otherwise be dealt with, and it gives a picture at once, instead of data whence a picture may be plotted. Lastly, it affords an excellent test whether any given series is generic or not; for when the portraits in the series make a good and clear composite it shows that medium values are much more frequent than extreme values, and therefore that the series may be considered a generic one; otherwise it is certainly not generic.

---

4. *Account of the Discovery of Six Ancient Dwellings, found under and near to British Barrows on the Yorkshire Wolds. By* J. R. MORTIMER.

Dwelling No. 1 is in connection with barrow No. 100, group 5, in the author's openings, and is situated at the eastern end of the barrow, which is of the long type. Its depth from the base of the mound was 6½ feet, with a floor surface of 9½ feet by 7½ feet, and it was entered by two inclining passages, 24 feet in length; the northern one being cut by the side trench of the barrow, showing in this case that the construction of the dwelling had preceded the excavation of the trench, and was therefore older than the barrow. In the material filling the dwelling and its passages were many streaks of burnt wood, a human femur, portions of an urn, and many animal bones, all probably the residue of feasting. A little distance from the dwelling were portions of three more dish-shaped urns, and traces of interments.

Dwelling No. 2 was situated within 30 ft. of an oval barrow, in which were cremated interments. It resembled the previous one in having two entrance-passages, and much burnt wood, indicating likewise its destruction by fire.

Nos. 3 and 4 are of a somewhat simpler kind than the preceding ones, having no entrance-passages. They consist of nearly circular excavations in the rock, from 3½ to 4½ feet in depth, and from 7 feet to 8½ feet in diameter, in which were found bones of the red deer and the urus.

No. 5 is of an entirely different type from those previously named: it had consisted of an inner and an outer circle of upright posts, measuring in diameter 21½ and 28 feet respectively, the impressions of which were well-preserved, and show that some had been pointed and driven into the ground, whilst others had been placed in holes dug into the ground with their thick ends downwards, and in some cases extending 2 feet to 3 feet upwards into the body of the mound. In the centre of the two circles was an oval grave, cut 4 feet into the rock, and containing the flexed human remains of a large male. In front of his face lay a crushed food-vase, and close to his left shoulder was a perforated axe-hammer. Clayey matter covered the grave, and extended to the outer circle of post-holes. This was believed to be the residue of the sides of the dwelling, in the centre of which its owner was interred, and afterwards the walls were pushed down over the grave and covered with a mound. The author suggests that the space between the two circles of uprights might have been used for storing heads of grain, and other provisions for winter use, at a time when, probably, man's dwelling was the only building he possessed for all purposes.

No. 6 resembles the last, and was found under barrow No. 41. Here also was a circular bed of a clayey nature, 15 feet in diameter, and with stake-holes nearly all round its margin. These stake-holes reached from 12 to 18 inches into the ground under the barrow, and in three cases 5 feet upwards into the body of the mound. Small branches of oak, ash, maple, and other trees, thought to be the remains of the wattled sides of the hut, had left their impressions in the circular bed of clayey matter, some of which showed cuts made with the axe and the saw, seemingly of metal. The dropping from the eaves of this hut had stained the ground all round with colouring from the thatch of the roof, which probably was the straw of wheat, as the author possesses carbonised grains of this cereal from the primary interment of an undoubted British barrow near. Unlike the previous dwelling, the occupier had not been interred within the walls of this circle, but just a few feet outside, towards the rising sun. The bones were accompanied by a delicately formed flint knife lying close to the right arm, and a finely ornamented food vase near the head. As in the previous case the dwelling had been crushed down at the time of interment, and carefully covered with the barrow, showing but a step between the habitation of the living and the house of the dead.

---

5. *On the Origin and Use of Oval Tool-stones.* *By* W. J. KNOWLES.

The author stated that the use of oval tool-stones was not clearly understood. Sir William Wilde, in the Catalogue of the Royal Irish Academy, defines them as oval or egg-shaped stones, more or less indented on one or both surfaces. He states that their use is problematical, and that they were 'denominated *Tilhuggersteens* by the Northern antiquaries, who consider them chippers of flint or stone, and believe that in working they held them between the finger and thumb applied to these side cavities.' Sir John Lubbock, in 'Prehistoric Times,' gives a somewhat similar account of them, and states that it is very doubtful whether they really belong to the Stone Age. Mr. John Evans, F.R.S., states in his Presidential Address to the Anthropological Institute on January 29, 1878, when referring to a case where one was found with flint scrapers and other objects, that 'if it could be proved that they were contemporaneous he would more readily accept the scrapers as being of the Age of Iron, than the tool-stones as belonging to that of Stone.' The author has found a few of these tool-stones with flint objects in the sandhills of Portstewart and Ballintoy, in the North of Ireland, and on one occasion he dug up half of a tool-stone closely associated with flint scrapers, flakes, hammer-stones, and cores at Ballintoy. He had frequently found stones with roughened and indented spots, which appeared to be oval tool-stones in an early stage of formation. In the sandhills of Dundrum, county Down, he obtained several of these among the flint objects; but during the summer of 1880, when excavating a spot which must have been the site of an ancient dwelling-place, he dug up a very perfect stone hatchet seven inches long, two flint knives, several scrapers, hammer-stones, and cores, and among these a stone of the tool-stone class having one central pitted spot. The finding of this pitted stone in such close proximity to cores, hammer-stones, and flakes, caused the author to believe that the flint implement-makers must have supported their cores or blocks of flint on a stone anvil, when about to dislodge flakes, by striking with the hammer-stone, and that such an operation constantly repeated would produce the pits on the anvil. This idea was confirmed by a similar anvil-stone of larger size, with hammer-stones, flakes, and cores, being turned out during excavations which the Marchioness of Downshire afterwards had made in Dundrum Sandhills, and he believed that the anvil-stone was just as necessary a part of the stock-in-trade of the flint implement-maker as the hammer-stones and cores. At Ballintoy, on a subsequent occasion, he obtained another of these anvil-stones, which had been split, and both in this one and several other broken specimens in the author's collection the split ran through the centre of the depression. In making an experiment to see the effect of repeatedly hammering at a core resting on a stone anvil, the author produced a pit in the anvil-stone identical in appearance with that on the tool-stones, but on continuing the operation the stone split exactly through the centre of the pit. He therefore believed that it was owing to repeated blows on the same spot that the stones had split through the centre.

In the author's collection of tool-stones the pits vary from mere roughening of the surface to deep cup-shaped hollows nearly meeting in the centre. In one specimen, which had been excavated and found to be in connection with flint flakes and cores, scratches are visible, showing how the core had jerked from the pitted part in the centre towards the circumference. He believed that the forming of pits by the operation of striking off flakes had given the idea of boring, and that many of the stone hammers had been bored in this way.

The author was of opinion that, if we conceive the idea that the tool-stones are anvils, there is no necessity for confining their use to any age. If they were of the Stone Age it was possible, and even likely, their use would descend to the age of Iron. He referred to a stone which he had seen in the Christy Collection in London some time ago, sticking in a mass of breccia, composed chiefly of flint flakes and fragments of broken bones, which had been brought from one of the rock shelters in France. This stone had a cup-shaped depression like the tool-stones. At the time he did not understand its use, but he had now no hesitation in saying that he believed it to be an anvil-stone, and that we must, therefore, carry back the use of the tool-stone, not only to the Stone Age, but to a very early Stone Age.

---

6. *On the Discovery of Flint Implements in stratified gravel in the Nile Valley, near Thebes. By* Major-General PITT-RIVERS, *F.R.S.* (formerly Colonel Lane-Fox).

General Pitt-Rivers visited Thebes in March 1881, and examined the gravel in the Nile Valley, to ascertain if the remains of flint implement manufacture could be found in it. He found flint flakes in the banks of the wady which runs down from the Tombs of the Kings. The section here shows 3 feet 9 inches of gravel on the top, composed of sub-angular and rounded stones of chert and limestone, then a seam of hard mud, and below that gravel again. The flakes were chiefly found beneath the seam of mud. This gravel had become so hard in Egyptian times that they were able to cut flat-topped tombs in it, supported by square pillars dried hard, which had retained the sharpness of the edges to the present day. Skulls and the remains of mummies and pottery were found in them, and some of the flint flakes were chiselled out of the sides of these tombs. The tombs, judged by the pottery found in them, have been pronounced by competent Egyptologists to be not later than the XVIII. dynasty and perhaps earlier, proving very great age for the formation of the gravel in which the tombs were cut. So long as the finds of flint implements were confined to the surface, doubts as to their contemporaneity with Egyptian civilisation might be fairly mooted, but the results of this discovery place beyond doubt the fact of their being of much earlier date. The paper was illustrated by plans and sections drawn to scale and showing the position of the flints.

SATURDAY, SEPTEMBER 3.

The following Report and Papers were read:—

1. *Report of the Anthropometric Committee.*—See Reports, p. 225.

---

2. *On a Collection of Racial Photographs. By* J. PARK HARRISON, *M.A.*

---

3. *On Scandinavian and Pictish Customs on the Anglo-Scottish Border. By* Dr. PHENÉ, *F.S.A., F.R.G.S.*

After adverting to the persistent retention of curious customs, and the handing down from generation to generation the traditionary lore of ages long past, the author referred to some of those which were corroborated by ancient monuments of an unusual kind still famous on the Scottish border. These consisted of sculptured stones, earthworks, and actual ceremonies.

Quoting from former writers, from family pedigrees, and other documents, it was shown that the estates to which pertained such strange matters as follow, had been held alternately by those claiming under the respective nationalities, or more local powers, and these, from their natural defensive features, must have been places of border importance earlier than history records.

The district is occupied by the descendants—often still traceable—of Danes, Jutes, Frisians, Picts, Scots, Angles, and Normans; and by a comparison of several of the languages of these people, as well ancient as now existing, and also of the Gothic, it was shown in relation to a particular class of the most curious monuments, that the Norse 'ormr,' Anglo-Saxon 'vyrm,' old German 'wurm,' Gothic 'vaúrms,' pronounced like our word worm; and the word 'lint' or 'lind,' also German, and the Norse 'linni,' are all equivalent, and mean serpent; and in some cases the two words are united as in the modern German 'lindwurm,' and the Danish and Swedish 'lindorm.' On this apparently rested the names of some of the places having these strange traditions, as Linton or serpent-town, Wormiston or worm's (ormr's) town, Lindisfarne, the Farne-serpent island, now Holy Island, &c., and also the various worm-hills, or serpent-mounds, of those localities.

It was curious that the contest (like that of St. George) was sometimes with two dragons, as shown on a sculptured stone in Linton Church, Roxburghshire, and on a similar stone at Lyngby in Denmark, in the churchyard, where there was a tradition that two dragons had their haunt near the church.

From these and other facts, the author concluded that the contests were international, and in the case of two dragons, an allied foe, either national, religious, or both, was overcome. He showed from the Scottish seals that Scotland used the dragon as an emblem, apparently deriving it from the Picts. That the Scandinavians also used it, and that these nationalities were antagonistic to the Saxon.

In the time of David the First of Scotland, the first great centralisation of Saxon power took place, and the powerful family of the Cumyns obtained, apparently by conquest, at least two of the localities having these strange traditions. Further, as the political object was to suppress the Celtic and Scandinavian, or other local national feeling, there could be little doubt that, however they obtained them, the persons dispossessed were of one or other of the Northern tribes. Hence, probably the middle-age tradition of the slaying of the serpent or dragon, or the serpent or dragon bearer, on the Anglo-Scottish border. But he considered such traditions would hardly have originated through such conquests, had not previous marvellous stories existed of the prowess and conquest by the dragon (bearers) of the lands they invaded, all the wonders of which would be transferred to the conqueror's conqueror. Hence these stories were not to be set aside with a sneer, as in them was a germ of history, giving us, perhaps, the only insight we could obtain of the prehistoric customs and mythology of some of the ancient tribes of Britain. Earthen mounds, tumuli, standing stones, &c., still existed in some of these localities, with all of which the dragon, serpent, or worm was associated in the legends.

The author then described his personal experiences in the still existing dragon ceremonies in the south of France and Spain, which were always either on the present national or former less important provincial frontiers, and which still formed the subjects of great ecclesiastical ceremonies.

One of the high ecclesiastical dignitaries of the North of England—the Bishop of Durham—is in the position of having to take part in such a ceremony. Whenever a bishop of that diocese enters the manor of Sockburn for the first time, the Lord of the Manor, who holds under the see of Durham, subject to the following tenure, has to present the bishop, '*in the middle of the river Tees*, if the river is fordable, with the falchion wherewith the champion Conyers destroyed the *worm, dragon*, or *fiery flying serpent*, which destroyed man, woman, and child' in that district, and an ancient altar, called '*Greystone*,' still marks where the dragon was buried.

The subject was illustrated with views of all the places referred to, on the Anglo-Scottish, French, and Spanish border countries, as well as drawings of the sculptures, funereal urns, and other antiquities belonging to each locality.

4. *On some Objects recently exhumed in Britain, of apparently Phœnician origin.* *By* Dr. Phené, *F.S.A., F.R.G.S.*

The places at or near which the objects were discovered were described as having in one case natural, in the other artificial, hillocks or tumuli of earth or stone simulating rude animal outlines. One of the localities was the vicinity of Dartmoor, the other that of the great serpentine mound, containing a chamber in the head, found by the author some years since not far from Loch Etive. In the first—Newton Abbot in Devonshire—had been found, some years since, at a depth of 25 feet below the surface, leaning against a prostrate oak tree, equally deeply buried, a rudely carved black oak figure, under two feet in height; at the last—North Ballachulish—a similar figure, nearly five feet high, including an attached pedestal. As to the simulation of animal forms, natural and artificial, both were referred to in America and in France, and in or near them in each such case had also been found figures somewhat similarly designed, but not in wood. But there were still existing figures in wood and stone of almost identical sizes and outlines in places long held by the Phœnicians, as Minorca, &c. A remarkable piece of evidently Assyrian sculpture, found in Lord Mount-Edgecumbe's estate in Devonshire, lent further probability, from its locality being known as that of once Phœnician occupation, and necessarily of importation in exchange for export tin, that the object at Newton Abbot was made or imported by those people; and the bronze head of a cow found in a bog in Ireland, having the Phœnician emblems upon it, seemed a further example of importation by them. The figure at North Ballachulish had a clearly Oriental feature. The eyes were formed of white stone inserted in the dark oak or ebony, and a recess at the base of the figure seemed evidently formed for a reliquary, and, with the sign of a crescent on the head, was pointed out by the author as a proof of its being an object for worship. This figure was also found at a depth from the surface, indicating a date as far back as the Phœnician traffic. The thickness of peat under which it lay has been estimated at 12 feet. It was shown that North Ballachulish and Newton Abbot were both secure and therefore valuable harbours, and the gold of Sutherland and tin of Devon were a sufficient inducement to attract Phœnician traders. Drawings of all the objects were exhibited.

MONDAY, SEPTEMBER 5.

The following Papers were read:—

1. *Notes on the Geographical Distribution of Mankind.* *By* Miss A. W. Buckland.

Commenting upon the fact that the Geographical Distribution of Man has not occupied the attention of naturalists so much as that of plants and animals, Miss Buckland quoted the 'Encyclopædia of Geography,' published in 1834, to show that, although great advances have been made in Anthropological research since the formation of the British Association, the problems of fifty years ago remain unsolved. Ethnologists are still divided into monogenists and polygenists, and although at present the monogenist theory is in the ascendant, little has yet been done towards the discovery of the original birthplace of the human species, or of that semi-human progenitor depicted by Darwin.

The origin of the black, the white, and the yellow races, distinctly depicted on Egyptian monuments five thousand years ago, remains undiscovered; whilst in almost every island of the Pacific may be found traces of one or more vanished races, differing from the two distinct peoples at present inhabiting them. The Australians form another separate race, which has been connected by Professor Huxley with the hill tribes of India, and also with the ancient Egyptians; but how and at what period they reached their present isolated position remains a geographical and ethnological puzzle. The Australians seem also to bear a resemblance to the earliest known men of Europe, in the form of the skull and the great prominence of the brow-ridges; but here also two races present themselves almost contemporaneously. These are known, from the form of the skull, as the dolicocephalic or long-headed, and the brachycephalic or round-headed races; and the researches of the late Dr. Broca seem to prove the former to have been undoubtedly the most ancient. The Palæolithic Age is divided into two periods—that of the Mammoth and that of the Reindeer. It is the men of the first period who resemble the Australians, whilst those of the reindeer period are identified by many anthropologists with the Esquimaux, and these are supposed to have been driven out by a brachycephalic race, bringing with them Neolithic weapons, a knowledge of agriculture, &c. The Palæolithic men are supposed to have come from Africa, whilst the Neolithic are traced by M. de Mortillet to Asia; but how and where the two types originated we cannot say. Madame Royer believes that brachycephaly arises from an increase of brain-development; but the Andamanese, a very low race, are brachycephalic. M. Hovelacque points out that the anthropoid apes of Africa are dolicocephalic, whilst those of Asia are round-headed, thus suggesting a local origin for the two forms of skull. The dispersion of these various races over the world was formerly accounted for by supposed extensions of existing land masses, and the existence of a submerged continent in the Pacific; but the researches of the *Challenger* have led Mr. Wallace and others to the conclusion that this continent never existed, and although certain extensions of existing lands are allowed, these alterations are supposed to have taken place long before the advent of man upon the earth. Thus the peopling of oceanic islands is left to chance, which, in the case of Australia, is rendered more difficult from the slight acquaintance of the natives with navigation, and from the fact of their differing in race from the Papuans and Tasmanians. Miss Buckland therefore believes that either some comparatively recent land connection with Africa or Asia must have existed, at present undiscovered, or that the antiquity of man must be extended to Miocene times, at which period Australia received its present fauna and flora by direct land connection with Asia.

In conclusion Miss Buckland looks upon the problems propounded by Latham in the 8th edition of the 'Encyclopædia Britannica,' as to the unity, the geographical origin, the antiquity, and the futurity of mankind, as still awaiting solution.

---

2. *On the Papuans and the Polynesians.* *By* C. STANILAND WAKE.

The author, after referring to the classification of the Oceanic Races made by Mr. Keane, proceeded to show the diversity of type presented by the Papuans, and also the great difficulty there is in fixing the race-character of the Polynesians. It was pointed out that the Polynesians and Papuans have various features in common, such as the beard, the full and expressive eye, and often a long and aquiline nose, and that the latter exhibit certain Caucasian features more strongly than the former. These are the prominent eyebrows, and great development of the general pilous system, which Dr. Topinard refers to as special characteristics of the Australian race, and which are not uncommon in individuals among the peoples of Western Europe. From this we must assume that, if the Polynesians belong to the so-called Caucasian stock, the Papuans must also be Caucasians; the latter, however, approaching more nearly the Semitic branch and the former the Aryan branch. The causes of the differences between the Polynesians and the Papuans were then considered. The primitive stock from which both have sprung is probably now represented by the Australian race, which had formerly a much wider extension than at present, as its special characteristics before mentioned are possessed by the Melanesian and Papuan races, and also by the Ainos and Todas. The presence of two types among the Australians shows that they are not a pure race, and probably they exhibit the influence of a Negrito element, which exists also among the Papuans and the Melanesians, and perhaps even among the Malays.

The existence in the Malay Archipelago and in New Guinea of peoples intermediate between the Papuans and Polynesians was then mentioned, the frizzly hair which those peoples and the Papuans possess being explained as due to the presence of a Negrito element. The Jewish features of some of the Papuans, which are often met with also among the Polynesians, is the result of Semitic influence. The fundamental type of both Polynesians and Papuans was straight-haired and long-headed, and might be called Austral-Caucasian. Reference was made to various arts, habits, and customs, and also to language, as confirming the conclusion that the Polynesians and Papuans are sprung from a common stock, although the latter have been largely affected by crossing with the Negrito race, and by the influence of an early Asiatic migration; and the former have been as largely affected by contact with a more modern Asiatic people, now represented by the Malays, both races having been further influenced by the intermixture of Arab and Indian blood, but the Papuans more especially.

---

3. *On Excavations in a camp called Ambresbury Banks in Epping Forest. By* General PITT-RIVERS, *F.R.S.* (formerly Colonel Lane-Fox).

This investigation has been conducted under the auspices of the Epping Forest Naturalists' field club. General Pitt-Rivers first drew attention, by means of an imaginary section, to the evidence to be derived from cuttings through the ramparts of camps, which he said was of a very definite and reliable character; all objects found on the old surface line beneath the ramparts being of the age of the earthwork. The result proved, by means of fragments of pottery and other small objects, that this camp is British or Romano-British, that is, British before or after the Roman conquest. The paper was illustrated by a plan and section of the camp.

---

4. *On the Relation of Stone Circles to Outlying Stones or Tumuli or Neighbouring Hills, with some inferences therefrom. By* A. L. LEWIS.

The author, from an examination of eighteen stone circles in Southern Britain, showed that their builders had in various ways made special references to different points of the compass, but most particularly to the N.E. He then showed, from a number of independent sources, ranging from the Prophet Ezekiel down to a foreign correspondent of the 'Daily News,' that other ancient structures had similar references, known to have arisen in connection with times and seasons, and various forms of nature-worship; that practices connected with such worship, and especially with sun and fire worship, have come down, even in this country, to the present time; and that circular buildings and open circles have been and are used for worship of this kind, and inferred from these facts that the British stone circles were used for sun-worship probably in the Druidic period. He then dwelt on the references to the N. and E. in the orientation of English churches, which he thought to be derived from the references to those quarters in the circles, as the Roman Catholic churches, whether in Rome or London, are not so placed, and he gave some curious details on this point. He concluded by drawing attention to the firm root taken by Christianity in the Druidic countries of Gaul and Britain, and the great influence exercised by those countries in the later Roman Empire, and especially in the establishment of Christianity as the State religion.

---

5. *Notes on some specimens of Saw-cuts and Drill-holes in hard Stones of Primeval Egyptian period. By* W. FLINDERS PETRIE.

While examining the constructions of the earliest Egyptian period, many proofs appeared of the methods of cutting hard stones, such as granite, diorite, basalt, &c.

The tools appear to have been of bronze, with jewelled cutting edges, probably of beryl or crystallised corundum (coarse ruby), as quartz is incapable of doing the work. The forms were straight saws and probably circular saws, and certainly tube-drills, like the modern diamond crown-drill. All these were about 15 hundredths of an inch thick, and the drills from $\frac{4}{10}$ths to 5 inches diameter. The cutting was rapid, advancing 1 inch in diorite with 27 feet of motion. The pressure and tractive force was very great (certainly many cwts.), the cutting edges having in a single motion scored out grooves $\frac{1}{200}$ inch deep in the sides of a cut in diorite. Thus altogether the method was more like that of a modern planing tool than like the grinding cut of a lapidary's wheel. The sarcophagi were usually sawn outside, and hollowed by rows of drill-holes.

The examples exhibited comprised casts of saw-cuts and drill-holes made by erroneous work on granite sarcophagi, saw-cuts and drill-holes in diorite and basalt, drill-holes in limestone, and a cast of a fine case of a tube drill-hole in granite, with part of the core still remaining, conclusively proving the form of the drill.

---

6. *On the Numeral and Philological Relations of the Hebrew, Phœnician, or Canaanitic Alphabet and the Language of the Khita Inscriptions. By* Hyde Clarke.

Aleph (Alpha) being used for 1, Beth (Beta) for 2, &c., their employment was regarded as casual. Mr. Clarke had nevertheless instituted an investigation into these numeral values to ascertain whether it is a law of language that One and Elephant or Ox, Two and House or Town, exist as the same root or word. This he found to be the case in many of what may be called the prehistoric or 'Turanian' languages. The result was to show that the affinities and origin of the alphabet are not Semitic, but Turanian. He then proceeded to consider what Turanian family furnished the prototype, and on examination with Canaanitic, he found it there. Some years ago he had discovered the Canaanite 3, in Samakhonitis, and this enabled him to test the series and to restore the Canaanitic numerals, and ascertain their place in language and their comparative philology. These observations conformed with those he had before made for Khita, and showed that the Canaanitic was a language adopted in these inscriptions and would furnish materials for their transcription. In reference to the position of the Khita itself in the history of the ancient world, Mr. Clarke pointed to the similarity of the Naga, a remarkable group of languages in India.

---

7. *The Early Colonisation of Cyprus and Attica, and its relation to Babylonia. By* Hyde Clarke.

Mr. Clarke reported the results of recent investigations of autonymous coins of Cyprus and Attica, of inscribed gems, and of the Cypriote syllabary. These had afforded conformable linguistic materials. Thus the Cypriote character like Aleph answers to Ne, but Ne signifies an Elephant. The character like Beth is Mo, and this signifies Town, a variant of House. Such relations are supported by the coins. The emblems on those of Salamis in Cyprus and the island of Salamis and on the coins of Attica read with the equivalent meanings in the corresponding illustrative languages. A gem in the collection of Major di Cesnola bears the inscription Ya-phou in Cypriote and Khita, and the objects include a spear, gazelle, and dog, which read Ya-phou. On a gem from the excavations at Menidi in Attica is the Cypriote character Ti, with a lion and stag, the word for both of which is Ti. Thus the whole of the evidence is conformable, and it points to this result, that the ancient Cypriote and Attic was related to the Akkad of Babylonia and constituted a West Babylonian occupation. This accounts, more efficiently than any other suggestion, for the accordance of the historic facts and archæological evidence.

8. *On the Animism of the Indians of British Guiana.* *By* Everard F. im Thurm.

---

9. *Origin and Primitive Home of the Semites.* *By* G. Bertin.

---

10. *On the Utilisation of the Memory.* *By* George Harris, *LL.D., F.S.A.*

The writer commenced by observing that, important as the memory is, not only in the pursuit of science but in the general conduct of life, proportionably important also must be its due and proper cultivation.

To artificial aids to memory he did not, however, attach much value; most of them indeed consisting in attempts to dispense with, rather than to aid, the memory.

Nevertheless, the power of the memory, by direct and proper cultivation, might be prodigiously extended.

The peculiar circumstances which most conduce to fix ideas in the memory were next discussed.

Different persons, he stated, differ more in respect to memory than with regard to any other power; and the memory, he considered, reflected the peculiar mental character and constitution of the individual.

The extent to which persons are able to voluntarily discharge from the memory the recollection of matters which are no longer serviceable to them was discussed. There can be no doubt, he said, that, everyone possesses to a large extent the power of determining what matters he will recollect, and that this is a power which is greatly improvable by exercise. He concluded that we have no direct power of the former kind, but that we are able to a great extent to cause ideas to fade from the memory.

In the case of animals, he believed that they have great power of retention, but no active voluntary power of recollection. In their case events are mainly, if not entirely, recalled by association.

---

11. *On the Cultivation of the Senses.* *By* George Harris, *LL.D., F.S.A.*

The writer, after pointing out the use and describing the operations of the different senses, in the case both of man and animals, proceeded to observe that, while in the contrivance and arrangement of the various systems of education, due provision has been made for the study of those different branches which are considered most useful in life, none of these systems are planned in accordance with the faculties of the mind; in consequence of which, while some of these faculties engross a very large share, others are quite neglected; and the discipline and cultivation of the senses in general are very little attended to, and in case of certain of the senses are entirely neglected. The writer demonstrated that each sense is of great practical value in its way, and each is also capable of being extensively improved by cultivation.

The co-operation and co-aid of the different senses, and also of the senses and the reason, he described, together with the manner in which, both in animal constitution and in the case of man, the deficiency or failure of one sense may be more or less compensated by the cultivation and increased activity of the others. The paper concluded with a concise inquiry as to whether, and to what extent, plants, in common with the lower animals, are endowed with sensation, or with any property analogous to it.

TUESDAY, SEPTEMBER 6.

The following Papers were read and Exhibitions made:—

1. *Traces of Man in the Crag. By* H. STOPES, *F.G.S.*

The probability of man having lived during the Crag has been suggested by several (Charlesworth, &c.)

Many deny it, nearly all doubt it. Their evidence is chiefly negative. This shell, from the Crag at Walton-on-the-Naze, now gives a positive to the negative evidence; and although it need not necessarily at once create belief in man's remote being, it ought not to be lightly cast on one side. It was found in the Crag, properly stratified (and not in the talus), by a gentleman having good knowledge of geology, who would not be unable to judge, or know the value, of marking well all the surroundings and exact position of the shell. Owing to a dislike of the effects of the discovery, he did not publish it at the time, and a little while ago gave the shell to me. The human face roughly cut upon it is of the rudest description, and is *very crude*, thereby the more consistent. The shell is very abundant at Walton. According to S. V. Wood, jun., the Walton Crag was deposited under some depth of water; not a beach as so much of the rest of the Red Crag. Hence the possibility of the deposition of the shell without injury. It is bored naturally (by a mollusc); the colour of the boring and of the markings agree. Any shell now cut shows white, and does not readily take the same colour. Without attaching undue importance to this solitary specimen of early art, the author's object in giving it prominence is that, should any other evidence occur to substantiate the belief in Crag Man's existence, the find may be known and tend to confirm the struggling belief in man's extreme antiquity.

---

2. *The Results of recent further Excavations in the Caves of Cefn, near St. Asaph, North Wales. By* Professor T. McK. HUGHES, *M.A.*, and Mrs. WILLIAMS WYNN.

The authors pointed out the evidence of the direction of the ice movement from the higher mountains of North Wales during the period of extreme glaciation, and referred to this period the transport, over the western watersheds into the Vale of Clwyd, of the felsites and other associated rocks which were made use of in the manufacture of the implements found in the caves, which, therefore, must all be post-glacial.

They next draw attention to the later or marine drifts of the Clwyd Valley, which are composed chiefly of the *débris* of the older drift, generally with all the clay washed out; but contain also granites from the north, flints which cannot have been derived from any part of Wales, and marine shells, of which only a few are arctic forms. These deposits, they pointed out, were obviously later than the true glacial drift. They then described the mode of occurrence in the caves of marine shells, in drift somewhat similar in appearance to the marine drift of the Vale of Clwyd; but showed that, from its manner of accumulation and associated angular *débris*, it was obviously washed in from above along fissures, and was not carried in during the period of submergence. As this drift was in and over the main mass of fossiliferous cave-earth, they inferred that all the yet known remains in the Cefn caves must be not only later than the period of extension of Snowdonian ice into that area, but must be subsequent to the submergence that marked the close of the period of great glaciation, and were even proved to be later than the emergence that brought the marine drifts up within reach of subaërial denudation. Specimens from the collection of Mrs. Williams Wynn were exhibited in illustration.

---

3. *Exhibition of a Roman bronze galeated Bust.* *By* Professor T. McK. Hughes, *M.A.*

This bronze, from the collection of the late Rev. S. Banks, was found near Cottenham, north of Cambridge.

The head was of the Marcus Aurelius type; but the particular interest of the object was in the helmet, which represented a human face, the character of which exactly resembled that of the *Dying Gaul.*

---

4. *Exhibition of Four Bronze Socketed Spears, probably ancient, from China.* *By* Professor T.McK. Hughes, *M.A.*

These spears, brought by the Rev. S. Banks from China, were chiefly marked by the deep rectangular, or angular, or rounded notch running up from the edge of the socket to the position in which a rivet would be usually placed in such an implement. The edge of the blade-portion was waved in some of the specimens.

---

5. *On a supposed Inscribed Stone, near Llanerchymedd, in Anglesea.*[1] *By* Professor T. McK. Hughes, *M.A.*

The author described a boulder standing in a field on the east of the Railway between Plascoedana and Mynyddmawr, about a mile south of Llanerchymedd, Anglesea. It is a portion of a mass of rock, in which two varieties of rock alternate. There are also variations in structure in the rock, coinciding in direction, but not exactly in extent, with the varieties in texture.

On the north side, as the stone lies, of the principal joints, the rock is cut across by small joints at right angles to the principal joints and ending abruptly at them. These are crossed obliquely by a less frequent and more irregular set. As the weather has opened out these divisional planes to a small depth, the effect produced is that of a series of parallel lines, of uniform length, cut into the stone along the edges, with here and there an oblique stroke, altogether bearing a strong superficial resemblance to the characters known as Oghams. As it is known that Runic characters are obscure—in fact, quite unreadable except by experts—local talk has naturally placed the Mynyddmawr boulder among the inscribed stones of Wales. The joints to which the characters are due can, however, be traced into the portions of the boulder where a different texture and structure have caused a different weathering; and a close examination shows that the supposed characters must be referred entirely to natural causes.

---

6. *On some late Celtic Engravings on a Slate Tablet, found at Towyn.* *By* J. Park Harrison, *M.A.*

This tablet was found, buried under drift sand, at Towyn, in Merionethshire, in 1879. It is covered with incised figures representing, in outline, arms and objects of domestic use. Several other relics were discovered at the same time, some of them associated with it, but not assisting materially in deciding the date of this interesting tablet. Some of the hatchet-head forms, however, resemble so closely iron axe-heads in the museum of the Royal Irish Academy at Dublin, that if we knew the date of the latter, it would go far to decide the question. But they were found in cranoges of uncertain age. The ornamentation of the figures on the tablet is clearly Celtic, and resembles, except in the rudeness of the execu-

[1] The Rev. W. Wynn Williams has already called attention to this boulder in the *Archæologia Cambrensis*, and refers the supposed characters to natural causes, which he challenges geologists to explain.

tion (due partly, perhaps, to the roughness of the slate), the work called 'Opus Hibernicum.' As human bones were found on the site, the tablet may be a funeral offering, representing objects which in earlier times it was the practice to bury with deceased chiefs.[1]

---

7. *On the Physical Characters and Proportions of the Zulus. By* C. ROBERTS, *F.R.C.S., and* GEORGE W. BLOXAM, *M.A., F.L.S., Assistant Secretary of the Anthropological Institute.*

A Committee, consisting of certain members of the Anthropological Institute and of the Anthropometric Committee of the British Association, among whom were Professor Flower, General Pitt-Rivers, Mr. F. Galton, and the authors, made a careful and exhaustive examination of the physical characters and proportions of the Zulus exhibited at the Westminster Aquarium and in several parts of this country during the last two years.

Sixteen males and three females were examined, and from an hour to an hour and a half was devoted to each individual.

The measurements were made by the authors with the greatest care and precision, and comprise 38 different dimensions of the body. The heights from the ground were those of the vertex, the ear, the chin, the top of the sternum, the umbilicus, the trochanters, the fork, the knee, and the largest part of the calf of the leg. The breadths and circumferences of the trunk, the lengths and girths of the arms and legs, and all the important dimensions of the head, face, and neck were also recorded. In addition to these measurements, other points were noted, such as the projection of the heel backwards, the relative length of the great and second toe; the colour of the skin, hair, and eyes; the condition of the teeth, the character of the features, the weight of the body, and the drawing strength of the arm. Outlines of the feet were also taken.

The various observations have been carefully tabulated, and the relative proportions of the body have been calculated taking the stature as unity, and represented, as is usual in tables of this kind, by 1,000. The Zulus examined were from the border-land between Natal and Zululand, and, although they had been in contact with Europeans, were of pure Zulu race. Of this fact we were assured by persons who were well acquainted with the Zulus in their own country. As they were brought to this country for the purpose of public exhibition, it is probable they were selected, to a certain extent, as good specimens of their race; but as they were far from uniform in stature and physique, they may be accepted as average representatives of the Zulu tribes. Of the 16 males examined, one was a boy of about 14 years of age, the remaining 15 being adults whose average age was about 22½ years. Three women only having been examined, the measurements made were not sufficient to furnish trustworthy average results.

The average stature of the 15 male adults was 170·7 centimètres, or 67·3 inches; one-third of an inch *less* than the average Englishman of the same age. The average chest-girth was 92 9 c.m., or 36·5 inches; one inch and a quarter *greater* than the average Englishman of the same age. The average weight (without clothes, for which 7 lbs. must be allowed) was 68·1 kilogrammes, or 151 lbs.; about 10 lbs. *greater* than the average Englishman of the same age. The average strength, as tested by the drawing power of the arm (as in drawing a bow), was 38·7 kilos., or 85·6 lbs.; about 8 lbs. greater than that of the average Englishman of the same age.

Thus we see that while the stature of the Zulus was slightly below that of Englishmen of the same age, the weight of the body was 10 lbs., the strength 8 lbs., and the chest-girth 1¼ inches, *greater*. It must be borne in mind, however, that the Zulus were kept in a condition of high physical training by their dancing and spear-throwing exhibitions, while the Englishmen were those of the general

[1] A full description of the figures has since been published with plates by Bernard Quaritch, 15, Piccadilly, London.

population of this country, following ordinary occupations. It must also be remembered that the chest-girth and strength are, in a great measure, dependent on and related to the weight, and the greater weight of the Zulus accounts for their greater chest-girth and strength.

With regard to the other physical characters noted, the heel was found to be similar to that of Europeans in nine cases; in six cases there was slight projection backwards, and in four cases this peculiarity was well-marked.

In only one case was the great toe found to be of the same length as the second toe: in all the other cases the great toe was the longest.

The colour of the skin varied between a light chocolate and a dark bronze, ranging through the shades of Broca's tests from No. 21 to No. 43.

In all the cases the eyes were very dark: 17 cases corresponding to Broca's test No. 1, and 2 to No. 2, and there was more or less pigmentation of the conjunctiva in all, although in the case of the women this was very slight. There was also pigmentation of the mucous membrane of the mouth in all the men except two, who were quite free from it, as were also the three women.

The hair was black, curly, and thick, and in three cases there was a slight beard, and a little hair on the limbs, but in all the other cases the skin was smooth, soft, and free from hair.

The teeth were remarkably sound, regular, and well-shaped in all the cases but of one, who showed some signs of caries. The lips were of varying thickness, and resembling the negroid type in all cases except one, which approached the European type. In seven cases the chin was small, and in only one case did the prominent negroid chin appear. The noses were flat and broad, but less so than those of the negroes of the West Coast of Africa.

The ears were remarkably small and well-shaped, resembling the small ears of the dark types of southern Europeans.

Under examination the men were amiable and good-tempered, and displayed a mild, sheepish disposition, strangely at variance with the fierceness of manner assumed by them when performing before the public.

---

8. *Exhibition of Stone Implements from Asia Minor.* *By* HYDE CLARKE.

---

9. *On certain Discoveries of Bronze Implements in and about Leeds.* *By* JOHN HOLMES.

---

10. *On the Profile of the Danes and Germans.* *By* J. PARK HARRISON, *M.A.*

Before anything can be done in the way of defining the racial peculiarities of the people of the United Kingdom, we must ascertain, as far as possible, what were the characteristics of the races, now forming our population, at the time they landed on our coasts. This can, however, only be done approximately; first, by comparison of cranial remains from early tumuli and graves; and, second, by selecting types from districts in which there is reason to believe the inhabitants have for centuries remained with least intermixture. It is believed that much may, by such means, be learnt on the subject.

Confining the inquiry to Germany and Denmark in the first instance, we learn from Schadow, who wrote on the subject about fifty years ago, that the pure German type showed, as a principal feature, a depressed nasal bone, and, consequently, a concave or incurved line from the root to near the nasal point, where there was more or less of a bulb. In addition to this the face is described as wide, and the forehead smooth; the lower part of the face long. The ear appears to have been fine, with a well-formed but not heavy lobe; the hair fair, and the eyes blue. The skulls from early graves are brachycephalic.

The above description applies equally well to the rural population of West

Sussex, as seen in the ranks of the militia. It is also found in the remoter parts of Surrey, and in other so-called Saxon counties. The same type prevails in the country districts in Sweden, and is not uncommon in some parts of France.

Now, the Danish profile (pure) presents a striking contrast to the above type; though the skull is of the same, or nearly the same, width, and the hair and eyes equally light. The forehead exhibits an apparent depression, due to the prominence of the brow-ridges, which are more or less continuous. The eye consequently has the appearance of being sunk. The nasal bone rises well above an imaginary line drawn from the root to the tip of the nose, and is often high. These features are found in a great majority of the skulls preserved in the Nordisch Museum, and also in the fine collection of the Royal College of Surgeons at Copenhagen, both obtained from early Danish tumuli. Many persons in the streets of Copenhagen present these cranial characteristics; and they are found still more frequently in country places. In addition to this, there appears to be an equally well-marked contrast in the ear of those Danes whose profiles approach most nearly to the early type. It consists, amongst other points, in a continuation of the channel or *fossa* (which exists in all ears, between the helix and the antihelix) quite up to the cheek. There is consequently no proper lobe, though many Danes, through mixture with Swedes and Germans, have, like the majority of English, a composite or uncertain kind of lobe. The lips are thin.

The same characteristics are recognisable in the inhabitants of Schleswig and Holstein, where one frequently meets with the Danish termination *sen*. They are met with also, though not so strongly marked (except in a few cases), in Belgium, where the patronymic is abbreviated, as in Wales and many parts of England.

The type is found in various districts in the United Kingdom. Indeed, it is spread over so large an area that, for this and other reasons, the opinion that is now received by the most eminent anthropologists in Paris and in this country —that the Belgæ and the Cymri were Celtic tribes,—requires the supplement (which M. Hovelacque considers perfectly scientific)—that the Danes were a tribe of the Cymri. Certainly it is time to put aside the view that the Celtic race is dark. It is not so in Ireland, Scotland, or France, except where there is a strong infusion of Iberian blood, which would not have altered the profile. In the Principality the Cymric type still exists in comparative purity, and is fair.

Danish skulls in the possession of Dr. Fraser at Dublin, obtained by himself from a battle-field in the neighbourhood of that city, exhibit precisely the same peculiarities as the crania in the museums at Copenhagen. Two skulls, presented by Professor B. Dawkins to the Welshpool Museum, and labelled 'Danish,' are in every respect similar. Also several dredged up from the bed of the Ouse, in the museum at York, exhibit the same characteristics. Others, found in the hollowed trunks of trees, and supposed to be Anglian, present the same cranial features, though in a modified degree. In the Scarborough Museum there is a skeleton from a neighbouring barrow that might be considered Danish were it not that the objects associated with it point to a British interment.

Now, the majority of skulls collected by Canon Greenwell from the round barrows of Yorkshire, so closely resemble early Danish crania that he has arrived, quite independently, at the conclusion that the fair-haired Briton and the early Dane were allied in blood. In other words, that the Danes proper were in race a Celtic, and not a Teutonic people.

---

11. *On a remarkable Human Skull found near York.* *By* Edward Allen, *F.G.S.*

This skull, which was exhibited, was found some years ago in the neighbourhood of York. It is very much elongated, and compressed at the sides. The sagittal suture is entirely obliterated, and its place supplied by an elevated ridge of dense bone. The bones of the skull are very thick and heavy. The author thinks it probable that the sagittal suture was anchylosed very early in the development of the skull, and this circumstance would cause the skull to lengthen, to allow the growth of the brain to take place. The coronal and lambdoidal sutures are well-developed. The skull will come under the class of Scaphocephalic Crania. The tubercles of the teeth are worn smooth, as is the case with the teeth in many of the Roman skulls found near York. From the peculiarity of the teeth, and the skull having been found along with Roman remains, it is probably a Roman skull.

DEPARTMENT OF ANATOMY AND PHYSIOLOGY.

CHAIRMAN OF THE DEPARTMENT—Professor J. S. BURDON SANDERSON, M.D., LL.D., F.R.S. (Vice-President of the Section).

THURSDAY, SEPTEMBER 1.

The Department did not meet.

FRIDAY, SEPTEMBER 2.

The CHAIRMAN delivered the following Address:—

The Discoveries of the past Half-Century relating to Animal Motion.

THE two great branches of Biology with which we concern ourselves in this Section, Animal Morphology and Physiology, are most intimately related to each other. This arises from their having one subject of study—the living animal organism. The difference between them lies in this, that whereas the studies of the anatomist lead him to fix his attention on the organism itself, to us physiologists it, and the organs of which it is made up, serve only as *vestigia*, by means of which we investigate the vital processes of which they are alike the causes and consequences.

To illustrate this I will first ask you to imagine for a moment that you have before you one of those melancholy remainders of what was once an animal—to wit, a rabbit—which one sees exposed in the shops of poulterers. We have no hesitation in recognising that remainder as being in a certain sense a rabbit; but it is a very miserable vestige of what was a few days ago enjoying life in some wood or warren, or more likely on the sand-hills near Ostend. We may call it a rabbit if we like, but it is only a remainder—not the thing itself.

The anatomical preparation which I have in imagination placed before you, although it has lost its inside and its outside, its integument and its viscera, still retains the parts for which the rest existed. The final cause of an animal, whether human or other, is muscular action, because it is by means of its muscles that it maintains its external relations. It is by our muscles exclusively that we act on each other. The articulate sounds by which I am addressing you are but the results of complicated combinations of muscular contractions—and so are the scarcely appreciable changes in your countenances by which I am able to judge how much, or how little, what I am saying interests you.

Consequently the main problems of physiology relate to muscular action, or, as I have called it, animal motion. They may be divided into two—namely (1) in what does muscular action consist—that is, what is the process of which it is the effect or outcome? and (2) how are the motions of our bodies co-ordinated or regulated? It is unnecessary to occupy time in showing that, excluding those higher intellectual processes which, as they leave no traceable marks behind them, are beyond the reach of our methods of investigation, these two questions comprise all others concerning animal motion. I will therefore proceed at once to the first of them—that of the process of muscular contraction.

The years which immediately followed the origin of the British Association exceeded any earlier period of equal length in the number and importance of the new facts in morphology and in physiology which were brought to light; for it was during that period that Johannes Müller, Schwann, Henle, and, in this country, Sharpey, Bowman, and Marshall Hall, accomplished their productive labours. But it was introductory to a much greater epoch—the greatest, I venture to say, beyond comparison, which has occurred in the history of Biology since that of the discovery of the circulation of the blood. It would give you a true idea of the nature of the great advance which took place about the middle of this century if I were to define it as the epoch of the death of 'vitalism.' Before that time, even the greatest biologists—*e.g.* J. Müller—recognised that the knowledge biologists possessed both of vital and physical phenomena was insufficient to refer both to a common measure. The method, therefore, was to study the processes of life in relation to each other only. Since that time it has become fundamental in our science not to regard any vital process as understood at all, unless it can be brought into relation with physical standards, and the methods of physiology have been based exclusively on this principle. Let us inquire for a moment what causes have conduced to the change.

The most efficient cause was the progress which had been made in physics and chemistry, and particularly those investigations which led to the establishment of the doctrine of the Conservation of Energy. In the application of this great principle to physiology the men to whom we are indebted are, first and foremost, J. R. Mayer, of whom I shall say more immediately; and secondly, the great physiologists still living and working among us, who were the pupils of J. Müller—viz., Helmholtz, Ludwig, du Bois-Reymond, and Brücke.

As regards the subject which is first to occupy our attention, that of the *process* of muscular contraction, J. R. Mayer occupies so leading a position that a large proportion of the researches which have been done since the new era, which he had so important a share in establishing, may be rightly considered as the working out of principles enunciated in his treatise[1] on the relation between organic motion and exchange of material. The most important of these were as expressed in his own words, (1) 'That the chemical force contained in the ingested food and in the inhaled oxygen is the source of the motion and heat which are the two products of animal life; and (2) that these products vary in amount with the chemical process which produces them.' Whatever may be the claims of Mayer to be regarded as a great discoverer in physics, there can be no doubt that as a physiologist he deserves the highest place that we can give him, for at a time when the notion of the correlation of different modes of motion was as yet very unfamiliar to the physicist, he boldly applied it to the phenomena of animal life, and thus re-united physiology with natural philosophy, from which it had been rightly, because unavoidably, severed by the vitalists of an earlier period.

Let me first endeavour shortly to explain how Mayer himself applied the principle just enunciated, and then how it has been developed experimentally since his time.

The fundamental notion is this: the animal body resembles, as regards the work it does and the heat it produces, a steam engine, in which fuel is continually being used on the one hand, and work is being done and heat produced on the other. The using of fuel is the chemical process, which in the animal body, as in the steam-engine, is a process of oxidation. Heat and work are the useful products,

[1] J. R. Mayer, *Die organische Bewegung in ihrem Zusammenhange mit dem Stoffwechsel: Ein Beitrag zur Naturkunde*, Heilbronn, 1845.

for as, in the higher animals, the body can only work at a constant temperature of about 100° Fahr., heat may be so regarded.

Having previously determined the heat and work severally producible by the combustion of a given weight of carbon, from his own experiments and from those of earlier physicists, Mayer calculated that if the oxidation of carbon is assumed to represent approximately the oxidation-process of the body, the quantity of carbon actually burnt in a day is far more than sufficient to account for the day's work, and that of the material expended in the body not more than one-fifth was used in the doing of work, the remaining four-fifths being partly used, partly wasted, in heat-production.

Having thus shown that the principles of the correlation of process and product hold good, so far as its truth could then be tested, as regards the whole organism, Mayer proceeded to inquire into its applicability to the particular organ whose function it is 'to transform chemical difference into mechanical effect'—namely, muscle. Although, he said, a muscle acts under the direction of the will, it does not derive its power of acting from the will any more than a steamboat derives its power of motion from the helmsman. Again (and this was of more importance, as being more directly opposed to the prevalent vitalism), a muscle, like the steamboat, uses, in the doing of work, not the material of its own structure or mechanism, but the fuel—*i.e.*, the nutriment—which it derives directly from the blood which flows through its capillaries. 'The muscle is the instrument by which the transformation of force is accomplished, not the material which is itself transformed.' This principle he exemplified in several ways, showing that if the muscles of our bodies worked, as was formerly supposed, at the expense of their own substance, their whole material would be used up in a few weeks, and that in the case of the heart, a muscle which works at a much greater rate than any other, it would be expended in as many days—a result which necessarily involved the absurd hypothesis that the muscular fibres of our hearts are so frequently disintegrated and reintegrated that we get new hearts once a week.

On such considerations Mayer founded the prevision, that, as soon as experimental methods should become sufficiently perfect to render it possible to determine with precision the limits of the chemical process either in the whole animal body or in a single muscle during a given period, and to measure the production of heat and the work done during the same period, the result would show a quantitative correlation between them.

If the time at our disposal permitted, I should like to give a short account of the succession of laborious investigations by which these previsions have been verified. Begun by Bidder and Schmidt in 1851,[1] continued by Pettenkofer and Voit,[2] and by the agricultural physiologists[3] with reference to herbivora, they are not yet by any means completed. I must content myself with saying that by these experiments the first and second parts of this great subject—namely, the limits of the chemical process of animal life and its relation to animal motion under different conditions—have been satisfactorily worked out, but that the quantitative relations of heat-production are as yet only insufficiently determined.

Let me sum up in as few words as possible how far what we have now learnt by experiment, justifies Mayer's anticipations, and how far it falls short of or exceeds them. First of all, we are as certain as of any physical fact that the animal body in doing work does not use its own material—that, as Mayer says, the oil to his lamp of life is food; but in addition to this we know, what he was unaware of, that what is used is not only not the living protoplasm itself, but is a kind of material which widely differs from it in chemical properties. In what may be called commercial physiology—*i.e.* in the literature of trade puffs—one still meets with the assumption that the material basis of muscular motion is nitrogenous; but by many methods of proof it has been shown that the true '*Oel in der Flamme des Lebens*' is not proteid substance, but sugar, or sugar-producing material. The

[1] Bidder and Schmidt, *Die Verdauungssaefte und der Stoffwechsel*, Leipzig, 1852.

[2] Pettenkofer and Voit, *Zeitschr. f. Biologie*, passim 1866–1880.

[3] Henneberg and Stohmann, *Beiträge zur Begrundung einer rationellen Futterung der Wiederkäuer*, Brunswick and Göttingen, 1860–1870.

discovery of this fundamental truth we owe first to Bernard (1850–56), who brought to light the fact that such material plays an important part in the nutrition of every living tissue; secondly, to Voit (1866), who in elaborate experiments on carnivorous animals, during periods of rest and exertion, showed that, in comparing those conditions, no relation whatever shows itself between the quantity of proteid material (flesh) consumed, and the amount of work done; and finally to Frankland, Fick and his associate Wislicenus, as to the work-yielding value of different constituents of food, and as to the actual expenditure of material in man during severe exertion. The subjects of experiment used by the two last-mentioned physiologists were themselves; the work done was the mountain ascent from Interlaken to the summit of the Faulhorn; the result was to prove that the quantity of material used was proportional to the work done, and that that material was such as to yield water and carbonic acid exclusively.

The investigators to whom I have just referred aimed at proving the correlation of process and product for the whole animal organism. The other mode of inquiry proposed by Mayer, the verification of his principle in respect of the work-doing mechanism—that is to say, in respect of muscle taken separately—has been pursued with equal perseverance during the last twenty years, and with greater success; for in experimenting on a separate organ, which has no other functions excepting those which are in question, it is possible to eliminate uncertainties which are unavoidable when the conditions of the problem are more complicated. Before I attempt to sketch the results of these experiments, I must ask your attention for a moment to the discoveries made since Mayer's epoch, concerning a closely related subject, that of the Process of Respiration.

I wish that I had time to go back to the great discovery of Priestley (1776), that the essential facts in the process of respiration are the giving off of fixed air, as he called it, and the taking in of dephlogisticated air, and to relate to you the beautiful experiments by which he proved it; and then to pass on to Lavoisier (1777), who, on the other side of the Channel, made independently what was substantially the same discovery a little after Priestley, and added others of even greater moment. According to Lavoisier, the chemical process of respiration is a slow combustion which has its seat in the lungs. At the time that Mayer wrote, this doctrine still maintained its ascendancy, although the investigations of Magnus (1838) had already proved its fallacy. Mayer himself knew that the blood possessed the property of conveying oxygen from the lungs to the capillaries, and of conveying carbonic acid gas from the capillaries to the lungs, which was sufficient to exclude the doctrine of Lavoisier. Our present knowledge of the subject was attained by two methods—viz., first, the investigation of the properties of the colouring matter of the blood, since called 'hæmoglobin,' the initial step in which was made by Professor Stokes in 1862; and secondly, the application of the mercurial air-pump as a means of determining the relations of oxygen and carbonic acid gas to the living blood and tissues. The last is a matter of such importance in relation to our subject that I shall ask your special attention to it. Suppose that I have a barometer, of which the tube, instead of being of the ordinary form, is expanded at the top into a large bulb of one or two litres capacity, and that, by means of some suitable contrivance, I am able to introduce, in such a way as to lose no time and to preclude the possibility of contact with air, a fluid ounce of blood from the artery of a living animal into the vacuous space—what would happen? Instantly the quantity of blood would be converted into froth, which would occupy the whole of the large bulb. The colour of the froth would at first be scarlet, but would speedily change to crimson. It would soon subside, and we should then have the cavity which was before vacuous occupied by the blood and its gases—namely, the oxygen, carbonic acid gas, and nitrogen previously contained in it. And if we had the means (which actually exist in the gas-pump) of separating the gaseous mixture from the liquid, and of renewing the vacuum, we should be able to determine (1) the total quantity of gases which the blood yields, and (2), by analysis, the proportion of each gas.

Now, with reference to the blood, by the application of the 'blood-pump,' as it is called, we have learnt a great many facts relating to the nature of respiration, particularly that the difference of venous from arterial blood depends not on the presence of 'effete matter,' as used to be thought, but on the less amount of oxygen held by its colouring matter, and that the blood which flows back to the heart from different organs, and at different times, differs in the amount of oxygen and of carbonic acid gas it yields, according to the activity of the chemical processes which have their seat in the living tissues from which it flows.[1] But this is not all that the blood-pump has done for us. By applying it not merely to the blood, but to the tissues, we have learnt that the doctrine of Lavoisier was wrong, not merely as regards the place, but as regards the nature of the essential process in respiration. The fundamental fact which is thus brought to light is this, that although living tissues are constantly and freely supplied with oxygen, and are in fact constantly tearing it from the hæmoglobin which holds it, yet they themselves yield no oxygen to the vacuum. In other words, the oxygen which living protoplasm seizes upon with such energy that the blood which flows by it is compelled to yield it up, becomes so entirely part of the living material itself that it cannot be separated even by the vacuum. It is in this way only that we can understand the seeming paradox that the oxygen, which is conveyed in abundance to every recess of our bodies by the blood-stream, is nowhere to be found. Notwithstanding that no oxidation-product is formed, it becomes latent in every bit of living protoplasm; stored up in quantity proportional to its potential activity—*i.e.* to the work, internal or external, it has to do.

Thus you see that the process of tissue-respiration—in other words, the relation of living protoplasm to oxygen—is very different from what Mayer, who localised oxidation in the capillaries, believed it to be. And this difference has a good deal to do with the relation of Process to Product in muscle. Let us now revert to the experiments on this subject which we are to take as exemplification of the truth of Mayer's forecasts.

The living muscle of a frog is placed in a closed chamber, which is vacuous—*i.e.* contains only aqueous vapour. The chamber is so arranged that the muscle can be made to contract as often as necessary. At the end of a certain period it is found that the chamber now contains carbonic acid gas in quantity corresponding to the number of contractions the muscle has performed. The water which it has also given off cannot of course be estimated. Where do these two products come from? The answer is plain. The muscle has been living all the time, for it has been doing work, and (as we shall see immediately) producing heat. What has it been living on? Evidently on stored material. If so, of what nature? If we look for the answer to the muscle, we shall find that it contains both proteid and sugar-producing material, but which is expended in contraction we are not informed. There is, however, a way out of the difficulty. We have seen that the only chemical products which are given off during contraction are carbonic acid gas and water. It is clear, therefore, that the material on which it feeds must be something which yields, when oxidised, these products, and these only. The materials which are stored in muscle are oxygen and sugar, or something resembling it in chemical composition.

And now we come to the last point I have to bring before you in connection with this part of my subject. I have assumed up to this moment that heat is always produced when a muscle does work. Most people will be ready to admit as evidence of this, the familiar fact that we warm ourselves by exertion. This is in reality no proof at all.

The proof is obtained when, a muscle being set to contract, it is observed that at each contraction it becomes warmer. In such an experiment, if the heat-capacity of muscle is known, the weight of the particular muscle, and the increase of temperature, we have the quantity of heat produced.

If you determine these data in respect of a series of contractions, arranging the experiments so that the work done in each contraction is measured, and immediately thereupon reconverted into heat, the result gives you the total product of the oxidation-process in heat.

If you repeat the same experiment in such a way that the work done in each contraction is not so reconverted, the result is *less* by the quantity of heat

[1] Ludwig's first important research on this subject was published in 1862.

corresponding to the work done. The results of these two experiments have been found by Professor Fick to cover each other very exactly. I have stated them in a table,[1] in which we have the realisation as regards a single muscle of the following forecast of Mayer's as regards the whole animal organism. 'Convert into heat,' he said, 'by friction or otherwise, the mechanical product yielded by an animal in a given time, add thereto the heat produced in the body directly during the same period, and you will have the total quantity of heat which corresponds to the chemical processes.' We have seen that this is realisable as regards muscle, but it is not even yet within reach of experimental verification as regards the whole animal.

I now proceed abruptly (for the time at our disposal does not admit of our spending it on transitions) to the consideration of the other great question concerning vital motion, namely the question how the actions of the muscles of an animal are so regulated and co-ordinated as to determine the combined movements, whether rhythmical or voluntary, of the whole body.

As everyone knows who has read the 'Lay Sermons,' the nature and meaning of these often unintentional but always adapted motions, which constitute so large a part of our bodily activity, was understood by Descartes early in the seventeenth century. Without saying anything as to his direct influence on his contemporaries and successors, there can be no doubt that the appearance of Descartes was coincident with a great epoch—an epoch of great men and great achievements in the acquirement of man's intellectual mastery over nature. When he interpreted the unconscious closing of the eyelids on the approach of external objects, the acts of coughing, sneezing, and the like, as mechanical and reflected processes, he neither knew in what part of the nervous system the mechanisms concerned were situated, nor how they acted.[2] It was not until a hundred years after, that Whytt and Hales made the fundamental experiments on beheaded frogs, by which they

[1] RELATION OF PRODUCT AND PROCESS IN MUSCLE.
(Founded on the results of one of Fick's experiments.)

Process.		
Sugar used	0·014	milligrammes.
Oxygen used	0·015	,,
Carbonic acid gas formed	0·021	,,
Product.		
Mechanical product	6670	grammemillimeters.
Its heat-value	15·6	milligrammeunits
Heat produced	39·0	,,
Total product reckoned as heat	54·6	,,

[2] Descartes' scheme of the central nervous mechanism, comprised all the parts which we now regard as essential to 'reflex action.' Sensory nerves were represented by threads (filets) which connected all parts of the body to the brain (*Œuvres*, par V. Cousin, vol. iv. p. 359); motor nerves by tubes which extended from the brain to the muscles; 'motor centres' by 'pores' which were arranged on the internal surface of the ventricular cavity of the brain and guarded the entrances to the motor tubes. This cavity was supposed to be kept constantly charged with 'animal spirits,' furnished to it from the heart by arteries specially destined for the purpose. Any 'incitation' of the surface of the body by an external object which affects the organs of sense does so, according to Descartes, by producing a *motion* at the incited part. This is communicated to the pore by the thread and causes it to open, the consequence of which is that the 'animal spirits' contained in the ventricular cavity enter the tube and are conveyed by it to the various muscles with which it is connected, so as to produce the appropriate motions. The whole system, although it was placed under the supervision of the '*âme raisonnable*' which had its office in the pineal gland, was capable of working independently. As instances of this mechanism Descartes gives the withdrawal of the foot on the approach of hot objects, the actions of swallowing, yawning, coughing, &c. As it is necessary that in the performance of these complicated motions, the muscles concerned should contract in succession, provision is made for this in the construction of the systems of tubes which represent the motor nerves. The weakness of the scheme lies in the absence of fact basis. Neither threads nor pores nor tubes have any existence.

showed that the involuntary motion which such preparations execute ceases when the whole of the spinal chord is destroyed—that if the back part of the chord is destroyed, the motions of the hind limbs, if the fore part, those of the fore limbs cease. It was in 1751 that Dr. Whytt published in Edinburgh his work on the involuntary motions of animals. After this the next great step was made within the recollection of living physiologists; a period to which, as it coincided with the event which we are now commemorating—the origin of the British Association —I will now ask your special attention.

Exactly forty-nine years ago Dr. Marshall Hall communicated to the Zoological Society of London the first account of his experiments on the reflex function of the spinal chord. The facts which he had observed, and the conclusions he drew from them, were entirely new to him, and entirely new to the physiologists to whom his communication was addressed. Nor can there be any reason why the anticipation of his fundamental discovery by Dr. Whytt should be held to diminish his merit as an original investigator. In the face of historical fact, it is impossible to regard him as the discoverer of the 'reflex function of the spinal chord,' but we do not the less owe him gratitude for the application he made of the knowledge he had gained by experiments on animals to the study of disease. For no one who is acquainted with the development of the branch of practical medicine which relates to the diseases of the central nervous system, will hesitate in attributing the rapid progress which has been made in the diagnosis and treatment of these diseases, to the impulse given by Dr. Marshall Hall to the study of nervous pathology.

In the mind of Dr. Marshall Hall the word reflex had a very restricted meaning. The term 'excito-motory function,' which he also used, stood in his mind for a group of phenomena of which it was the sole characteristic that a sensory impression produced a motor response. During the thirty years which have elapsed since his death the development of meaning of the word reflex has been comparable to that of a plant from a seed. The original conception of reflex action has undergone, not only expansion, but also modification, so that in its wider sense it may be regarded as the empirical development of the philosophical views of the animal mechanism promulgated by Descartes. Not that the work of the past thirty years by which the physiology of the nervous system has been constituted, can be attributed for a moment to the direct influence of Descartes. The real epochmaker here was Johannes Müller. There can be no doubt that Descartes' physiological speculations were well known to him, and that his large acquaintance with the thought and work of his predecessors conduced, with his own powers of observation, to make him the great man that he was; but to imagine that his ideas of the mechanism of the nervous system were inspired, or the investigations, by which, contemporaneously with Dr. Marshall Hall, he demonstrated the fundamental facts of reflex action, were suggested by the animal automatism of Descartes, seem to me wholly improbable.

I propose, by way of conclusion, to attempt to illustrate the nature of reflex action in the larger sense, or, as I should prefer to call it, the Automatic Action of Centres, by a single example—that of the nervous mechanism by which the circulation is regulated.

The same year that J. R. Mayer published his memorable essay, it was discovered by E. H. Weber that, in the vagus nerve, which springs from the medulla oblongata and proceeds therefrom to the heart, there exist channels of influence by which the medulla acts on that wonderful muscular mechanism. Almost at the same time with this, a series of discoveries[1] were made relating to the circulation,

[1] The dates of the discoveries relating to this subject here referred to are as follows:—Muscular Structure of Arteries, Henle, 1841; Function of Cardiac Vagus, E. H. Weber, 1845; Constricting Nerves of Arteries, B. Séquard, 1852, Aug. Waller, 1853; Cardiac Centre, Bernard, 1858; Vascular Centre, Schiff, 1858; Dilating Nerves, Schiff, 1854; Eckhard, 1864; Lovén, 1866. Of the more recent researches by which the further elucidation of the mechanism by which the distribution of blood is adapted to the requirements of each organ, the most important are those of Ludwig and his pupils and of Heidenhain.

which, taken together, must be regarded as of equal importance with the original discovery of Harvey. First, it was found by Henle that the arterial blood-vessels by which blood is distributed to brain, nerve, muscle, gland, and other organs, are provided with muscular walls like those of the heart itself, by the contraction or dilatation of which the supply is increased or diminished according to the requirements of the particular organ. Secondly, it was discovered simultaneously, but independently, by Brown-Séquard and Augustus Waller, that these arteries are connected by nervous channels of influence with the brain and spinal cord, just as the heart is. Thirdly, it was demonstrated by Bernard, that what may be called the heart-managing channels spring from a small spot of grey substance in the medulla oblongata, which we now call the 'heart-centre'; and a little later by Schiff, that the artery-regulating channels spring from a similar head-central office, also situated in the medulla oblongata, but higher up, and from subordinate centres in the spinal cord.

If I had the whole day at my disposal and your patience were inexhaustible, I might attempt to give an outline of the issues to which these five discoveries have led. As it is, I must limit myself to a brief discussion of their relations to each other, in order that we may learn something from them as to the nature of automatic action.

Sir Isaac Newton, who although he knew nothing about the structure of nerves, made some shrewd forecasts about their action, attributed to those which are connected with muscles an alternative function. He thought that by means of motor nerves the brain could determine either relaxation or contraction of muscles. Now as regards ordinary muscles we know that this is not the case. We can will only the shortening of a muscle, not its lengthening. When Brown-Séquard discovered the function of the motor nerves of the blood-vessels, he assumed that the same limitation was applicable to it as to that of muscular nerves in general. It was soon found, however, that this assumption was not true in all cases—that there were certain instances in which, when the vascular nerves were interfered with, dilatation of the blood-vessels, consequent on relaxation of their muscles, took place; and that, in fact, the nervous mechanism by which the circulation is regulated is a highly-complicated one, of which the best that we can say is that it is perfectly adapted to its purpose. For while every organ is supplied with muscular arteries, and every artery with vascular nerves, the influence which these transmit is here relaxing, there constricting, according (1) to the function which the organ is called upon to discharge; and (2) the degree of its activity at the time. At the same time the whole mechanism is controlled by one and the same central office, the locality of which we can determine with exactitude by experiment on the living animal, notwithstanding that its structure affords no indication whatever of its fitness for the function it is destined to fulfil. To judge of the complicated nature of this function we need only consider that in no single organ of the body is the supply of blood required always the same. The brain is during one hour hard at work, during the next hour asleep; the muscles are at one moment in severe exercise, the next in complete repose; the liver, which before a meal is inactive, during the process of digestion is turgid with blood, and busily engaged in the chemical work which belongs to it. For all these vicissitudes the tract of grey substance which we call the *vascular centre* has to provide. Like a skilful steward of the animal household, it has, so to speak, to exercise perfect and unfailing foresight, in order that the nutritive material which serves as the oil of life, for the maintenance of each vital process, may not be wanting. The fact that this wonderful function is localised in a particular bit of grey substance is what is meant by the expression 'automatic action of a centre.'

But up to this point we have looked at the subject from one side only.

No state ever existed of which the administration was exclusively executive—no government which was, if I may be excused the expression, absolutely absolute. If in the animal organism we impose on a centre the responsibility of governing a particular mechanism or process, independently of direction from above, we must give that centre the means of being itself influenced by what is going on in all parts of its area of government. In other words, it is as essential that there should be channels of information passing inwards, as that there should be channels of influence passing outwards. Now what is the nature of these channels of information? Experiment has taught us not merely with reference to the regulation of the circulation, but with reference to all other automatic mechanisms, that they are as various in their adaptation as the outgoing channels of influence. Thus the vascular centre in the medulla oblongata is so cognisant of the chemical condition of the blood which flows through it, that if too much carbonic acid gas is contained in it, the centre acts on information of the fact, so as to increase the velocity of the blood-stream, and so promote the arterialisation of the blood. Still more strikingly is this adaptation seen in the arrangement by which the balance of pressure and resistance in the blood-vessels is regulated. The heart, that wonderful muscular machine by which the circulation is maintained, is connected with the centre, as if by two telegraph wires—one of which is a channel of influence, the other of information. By the latter, the engineer who has charge of that machine sends information to headquarters whenever the strain on his machine is excessive, the certain response to which is relaxation of the arteries and diminution of pressure. By the former, he is enabled to adapt its rate of working to the work it has to do.

If Dr. Whytt, instead of cutting off the head of his frog, had removed only its brain—*i.e.* the organ of thought and consciousness—he would have been more astonished than he actually was at the result; for a frog so conditioned exhibits as regards its bodily movements as perfect adaptedness as a normal frog. But very little careful observation is sufficient to show the difference. Being incapable of the simplest mental acts, this true animal automaton has no notion of requiring food or of seeking it, has no motive for moving from the place it happens to occupy, emits no utterance of pleasure or distress. Its life-processes continue so long as material remains, and are regulated mechanically.

To understand this all that is necessary is to extend the considerations which have been suggested to us in our very cursory study of the nervous mechanism by which the working of the heart and of arteries is governed, to those of locomotion and voice. Both of these we know, on experimental evidence similar to that which enables us to localise the vascular centre, to be regulated by a centre of the same kind. If the behaviour of the brainless frog is so natural that even the careful and intelligent observer finds it difficult to attribute it to anything less than intelligence, let us ask ourselves whether the chief reason of the difficulty does not lie in this, that the motions in question are habitually performed intelligently and consciously. Regarded as mere mechanisms, those of locomotion are no doubt more complicated than those of respiration or circulation, but the difference is one of degree, not of kind. And if the respiratory movements are so controlled and regulated by the automatic centre which governs them, that they adapt themselves perfectly to the varying requirements of the organism, there is no reason why we should hesitate in attributing to the centres which preside over locomotion powers which are somewhat more extended.

But perhaps the question has already presented itself to your minds, What does all this come to? Admitting that we are able to prove (1) that in the animal body, Product is always proportional to Process, and (2), as I have endeavoured to show you in the second part of my discourse, that Descartes' dream of animal automatism has been realised, what have we learnt thereby? Is it true that the work of the last generation is worth more than that of preceding ones?

If I only desired to convince you that during the last half-century there has been a greater accession of knowledge about the function of the living organism than during the previous one, I might arrange here in a small heap at one end of the table the physiological works of the Hunters, Spallanzani, Fontana, Thomas Young, Benjamin Brodie, Charles Bell, and others, and then proceeding to cover the rest of it with the records of original research on physiological subjects since 1831, I should find that, even if I included only genuine work, I should have to heap my table up to the ceiling. But I apprehend this would not give us a true answer to our question. Although etymologically, Science and Knowledge mean the same thing, their real meaning is different. By science we mean, first of all, that knowledge which enables us to sort the things known according to their true relations. On this ground we call Haller the father of physiology, because, regardless of existing theories, he brought together into a system, all that was then known by observation or experiment as to the processes of the living body. But in the 'Elementa Physiologiæ' we have rather that out of which science springs than science itself. Science can hardly be said to begin until we have by experiment acquired such a knowledge of the relation between events and their antecedents, between processes and their products, that, in our own sphere, we are able to forecast the operations of nature, even when they lie beyond the reach of direct observation. I would accordingly claim for physiology a place in the sisterhood of the sciences, not because so large a number of new facts have been brought to light, but because she has in her measure acquired that gift of prevision which has been long enjoyed by the higher branches of natural philosophy. In illustration of this, I have endeavoured to show you that every step of the laborious investigations undertaken during the last thirty years as to the process of nutrition, has been inspired by the previsions of J. R. Mayer, and that what we have learnt with so much labour by experiments on animals is but the realisation of conceptions which existed 200 years ago in the mind of Descartes as to the mechanism of the nervous system. If I wanted another example I might find it in the previsions of Dr. Thomas Young as to the mechanism of the circulation, which for thirty years were utterly disregarded, until at the epoch to which I have so often adverted, they received their full justification from the experimental investigations of Ludwig.

But perhaps it will occur to some one that if physiology founds her claim to be regarded as a science on her power of anticipating the results of her own experiments, it is unnecessary to make experiments at all. Although this objection has been frequently heard lately from certain persons who call themselves philosophers, it is not very likely to be made seriously here. The answer is, that it is contrary to experience. Although we work in the certainty that every experimental result will come out in accordance with great principles (such as the principle that every plant or animal is, both as regards form and function, the outcome of its past and present conditions, and that in every vital process the same relations obtain between expenditure and product as hold outside of the organism), these principles do little more for us than indicate the direction in which we are to proceed. The history of science teaches us that a general principle is like a ripe seed, which may remain useless and inactive for an indefinite period, until the conditions favourable to its germination come into existence. Thus the conditions for which the theory of animal automatism of Descartes had to wait two centuries, were (1) the acquirement of an adequate knowledge of the structure of the animal organism, and (2) the development of the sciences of physics and chemistry; for at no earlier moment were these sciences competent to furnish either the knowledge or the methods necessary for its experimental realisation; and for a reason precisely similar Young's theory of the circulation was disregarded for thirty years.

I trust that the examples I have placed before you to-day may have been sufficient to show that the investigators who are now working with such earnestness in all parts of the world for the advance of physiology, have before them a definite and well-understood purpose, that purpose being to acquire an exact knowledge of the chemical and physical processes of animal life, and of the self-acting machinery by which they are regulated for the general good of the organism. The more singly and straightforwardly we direct our efforts to these ends, the sooner we shall attain to the still higher purpose—the effectual application of our knowledge for the increase of human happiness.

The Science of Physiology has already afforded her aid to the Art of Medicine in furnishing her with a vast store of knowledge obtained by the experimental investigation of the action of remedies and of the causes of disease. These investigations are now being carried on in all parts of the world with great diligence, so that we may confidently anticipate that during the next generation the progress of pathology will be as rapid as that of physiology has been in the past, and that as time goes on the practice of medicine will gradually come more and more under the influence of scientific knowledge. That this change is already in progress we have abundant evidence. We need make no effort to hasten the process, for we may be quite sure that, as soon as science is competent to dictate, art will be ready to obey.

The following Papers were read:—

1. *On the Development of the Colour-sense.* *By* Dr. Montagu Lubbock.

The author remarked that this was a subject which had only been discussed within the last five and twenty years. Mr. Gladstone was the first to open this question, his studies of the Homeric poems leading him to remark how few colours were mentioned by that poet, and how inexactly the colour-terms were used. This Mr. Gladstone accounted for, in his 'Studies on Homer and the Homeric Age,' published in 1858, by supposing that Homer's perceptions of colour were vague and indeterminate, owing to the organ of colour and its impressions being but partially developed among the Greeks of his age.

The author then stated that the object of the paper was to discuss the question whether there was evidence to show that the power of perceiving colour had been gradually acquired, not only by man in historic or prehistoric times, but by the animal kingdom at large.

The first explained briefly the meaning of the term 'Colour Sense,' or 'Perception of Colour,' observing that Newton first showed the white light of the sun to be formed of seven colours; that these seven colours could be observed separately, and in a certain definite order, if the white light of the sun was decomposed by means of a prism, and that mankind had been supposed to acquire perception of the different colours in the order of the colours of the solar spectrum.

The author observed that colour-blindness had been supposed to be a return to the primitive condition of vision in mankind, but that since red-colour-blindness was the usual form of that complaint, whereas red was supposed to be the first colour seen by man, there were no grounds for this supposition.

The author then recalled what had been already written on this subject. Mr. Gladstone had first opened the subject, as already stated, Lazarus Geiger having been the next to take up the question, in a paper read at Frankfort-on-the-Maine in 1867. Geiger believed the power of perceiving colour to have been gradually acquired, and *that* even within historic times. Neither in the Vedas of the Hindus, nor in the Zendavesta of the Parsees, had he found indications of developed colour-perception, any mention of blue colour being entirely absent from both, though the sky, on the one hand, and light on the other, were specially considered. Similarly no mention was made of green colour either in the Rigveda hymns or in the Zendavesta, though both often speak of the earth and its vegetation. In 1867 Hugo Magnus wrote a work upon this subject, entitled 'Die Entwickelung des Farbensinnes.' Believing in the same progressive appreciation of colours as Geiger, he supposed that at first mankind merely perceived white and black, the presence or absence of light; that red was the first colour to be recognised, the power of perceiving the other colours being gradually acquired in the order of the colours in the solar spectrum, from the red to the violet end. Magnus believed that it was whilst red and black were alone distinguished that the hymns of the Vedas were written, that yellow was also recognised in the time of Homer, and that it was only at a later date that the perception of green followed, the recognition of blue and violet coming last, that the evolution of the colour-sense was still incomplete, and that the time would come when the ultra-violet rays would be appreciated by the human eye.

The subject of the colour-sense was more thoroughly investigated by Grant Allen, in a work published in 1879. He pointed out that three periods of geological vegetation may be supposed to have existed, termed respectively the age of flowerless, the age of anemophilous, and the age of entomophilous plants. That in the Carboniferous period there exist traces of insects, which insects must have sought their food in the flowerless plants of that age. That plants would thus be fertilised by means of insects, the plants most attractive to insects gaining ground not only from thus having a more sure method of impregnation than the wind, but also because the seedlings due to such cross fertilisation are the most vigorous. Again, the colour-sense would become more and more perfect in insects, owing to the advantage which improved colour-sense would give them in their search for food, and these insects would have handed down this power to their insect descendants now living. Similarly Grant-Allen believed colour-perception to have been first aroused in simple marine animals by the animal organisms around them, and to have been from them handed down to the fishes and reptiles, and more remotely to the birds and 'mammals.' Man (the supposed descendant of fruit-eating quadrumana, who possessed colour-sense in a high degree) would thus have very perfect colour-perception. This has been shown to be equally pronounced in all varieties of the species, not only by the works of travellers and others respecting modern savages, but by information received from missionaries, Government officials, and others living among uncivilised races. That the colour-sense existed in an equally developed condition in ancient times is probable, owing to the character of the ancient monuments in Egypt, Assyria, and other parts, and to the traces of colour-perception which exist in the Old Testament. Similarly there are indications that perception of colour existed in the Bronze, and even in the Stone Age. Thus while coloured ornaments and beads have been found in the Swiss lake-dwellings, which are supposed to have belonged to the Bronze Age, stones remarkable for their colour seem to have been chosen in the Stone age, not only for use but also for ornament. Again observations made at the request of Holmgren upon various savage tribes point to similar conclusions, and Hugo Magnus has therefore acknowledged his previous conclusions not to be borne out by actual observation, admitting that it is not safe to conclude from a deficiency of language that there exists a corresponding deficiency of perception.

The author then considered the value of the arguments brought forward, showing that the arguments in favour of the gradual development of the colour-sense in man within historic times were merely philological, and that observations among the uncivilised races now living had shown that the extent of the colour-perception is not indicated by the variety of terms used to express it. The fact that the most uncivilised savages had good colour-perception, and the character of the monuments in Mycenæ, Assyria, and Egypt, which show how developed the perception of colour was when they were built, point to the same conclusion, that the colour-sense cannot have been gradually developed within the last few thousand years. The same was shown by the Old Testament scriptures, while coloured articles belonging to the Bronze or Stone Age indicated the existence of a good colour-sense in those times. Whatever therefore man had left behind tended to show that he had always possessed good colour-perception. As to its gradual development in the animal kingdom, though colour-perception probably did become more perfect in those insects which lived upon coloured food and in marine animals on account of the advantage, whether protective, attractive, or other which the colour-sense would give them, there was no proof that this power was from the latter 'handed down to the fishes and reptiles, and more remotely to the birds and mammals.' The following conclusions were therefore arrived at—firstly, that in man no such gradual development of the colour-sense could have taken place; secondly, that in animals, though it was not impossible that such might have occurred, and that colour-perception might have reached its present condition by the process of evolution, this statement had not been verified by actual observation.

---

2. *On the Function of the Two Ears in the Perception of Space. By* Professor SILVANUS P. THOMPSON, *B.A., D.Sc.*

The author remarked that the conceptions formed in our minds of the extension of space might be resolved into two parts—first, the conception of distance independent of direction; and, secondly, the conception of direction independent of distance. These conceptions were based upon the perceptions of three separate senses—muscular, optical, and auditory. Those of the first two classes were fairly well known, the problems of the optical perception of space having been worked out by Wheatstone, Helmholtz, and others. The perceptions of space dependent on the ear had been but imperfectly investigated. Theories had been put forward and observations made by Anton, Steinhauser, Graham Bell, E. Mach, Lord Rayleigh, Luca, Kupper, A. M. Mayer, and by himself. The author reviewed various theories and observations which had been made. Steinhauser and Graham Bell assumed the perception of direction to depend upon the relative intensity with which a sound reached the two ears. Mach and Lord Rayleigh regarded the perception as depending rather upon the relative differences of quality in the two ears, these differences being due to the partial resolution of compound tones, according to Mach, by reason of the ear-cavities acting as resonators, but according to Lord Rayleigh by reason of diffraction of the sound-waves around the head. The author, in a paper on 'Binaural Audition,' read to this Section in 1878, had shown that differences of phase were also of influence in the acoustic perception of direction. The author also referred to a paper read by him before the Association in 1879 on the Pseudophone, an instrument for investigating the laws of binaural audition by the illusions it produces in the acoustic perception of space. After discussing the merits of the various theories to account for the facts of observation upon tones of different degrees of intensity, pitch, phase, and quality, the author propounded the following theory:—'Judgments as to the direction of sounds are based in general upon the sensations of different intensity in the two ears, but the perceived difference of intensity upon which a judgment is based is not usually the difference in intensity of the lowest or fundamental tone of the compound sound (or "clang"), but upon the difference in intensity of the individual tone or tones of the clang for which the intensity-difference has the greatest effective result on the quality of the sound.' The author concluded with some remarks and suggestions as to the influence on the perception of sounds of the form of the convolutions of the pinnæ of the ears, and with the suggestion that now that the physical bases of the problem had been laid down, the problems of the acoustic perception of space would be greatly elucidated by experiments upon persons possessed of abnormal hearing, and upon the blind, in whom this perception is abnormally developed.

---

3. *A Contribution to the Question on the Influence of Bacilli in the Production of Disease. By* Professor J. COSSAR EWART, *M.D.*

About the end of March a new form of fever made its appearance in Aberdeen. The fever began with the usual symptoms—there was a well-marked rigor, then a sensation of coldness for some hours, accompanied with great depression, the pulse was rapid, and the temperature steadily increased to 103, in some cases to 105 deg. Fahrenheit. In the worst cases there was delirium. One of the most characteristic symptoms was an affection of the deep cervical glands and lymphatics near the angle of the jaw; the glands enlarged, and there was a feeling of fulness about the throat, congestion of the tonsils, and pain along the course of the lymphatics of the affected side of the neck. In from twenty-four to forty-eight hours the fever subsided, leaving the patient in a very exhausted state. In most cases there was a relapse which corresponded exactly with the first attack, with this difference, that a different set of glands and lymphatics were affected. After this relapse there was again apparent recovery and then a second relapse. In some cases there were as many as six relapses, the relapses occurring regularly every second day. In nearly all the cases recovery was slow, and in some abscesses formed near the angle of the jaw. In three cases the disease proved fatal. When an inquiry was instituted it was found that over 300 individuals had suffered from this disease, and that all the sufferers had been using milk from the same dairy. A sample of milk secured for examination, when the epidemic was at its height, was found to contain numerous micrococci, fungi spores, and spores which resembled those of Bacillus anthracis—the organism which is associated with splenic fever. When cultivated the spores germinated into exceedingly delicate bacilli, which on further cultivation lengthened into spore-bearing filaments. On inoculating rats with the milk containing the spores death followed in from eighteen to twenty-four hours. The tissues of these rats, especially in the region of the neck, were infiltrated with bacilli, which on cultivation developed into spore-bearing filaments. Inoculation proved both bacilli and spores to be as virulent as the original spores found in the milk. Confirmatory evidence of the relation of the bacillus to the disease, and of the disease to the bacillus, was obtained by the examination of pus from an abscess situated near the angle of the jaw of one of the sufferers. This pus contained spores and bacilli similar to those found in, or developed from, the milk. When a rat was inoculated with a minimal quantity of this pus, it suffered and died in the same way as the rats which were infected with the milk. Further investigations proved that the organisms had been added to the milk along with water. The water used at the dairy previous to the epidemic passed through a large concrete cistern (provided with a rough loose wooden cover) placed in a corner of the byre immediately over the heads of several cows. The spores reached the byre along with the steamed hay used as food. Once in the byre, the spores could have had little difficulty in entering the water cistern, which was practically a part of the byre. How they reached the tank in which the hay was steamed has not yet been discovered.

Experiments, after the methods employed by Burdon Sanderson, Pasteur, Greenfield, and Büchner showed—(1) that this bacillus could not be converted into the hay bacillus (*B. subtilis*); (2) that the cultivations diminished in virulence until they became quite innocuous; (3) that when the filaments were kept for a time at a temperature which prevented the appearance of spores, the virulence became attenuated and ultimately disappeared. Further experiments may show that the attenuated forms are capable of affording protection from the active bacilli.

In conclusion it was mentioned that the bacillus could be cultivated on the fresh-cut surfaces of potatoes and in gelatine—the recent methods described by Koch.

---

4. *On a little-known Cranial Difference between the Catarrhine and Platyrrhine Monkeys. By* W. A. FORBES, *B.A.*

Besides the well-known difference in the dentition, and in the form of the external auditory *meatus*, in the monkeys of the old and new worlds, there is a difference in the formation of the bony walls of the temporal fossa which in nearly every case suffices to distinguish at once the skull of a member of one of these groups from that of one of the other. As independently discovered by the author ('P.Z.S.' 1880, p. 639), and Dr. Gustav Joseph ('Morphologisches Jahrbuch,' i., pp. 453–465), in the Platyrrhine monkeys the parietal bone is prolonged forwards to meet the malar, there being a well-marked suture usually between the two, the frontal being in consequence altogether excluded, superficially at least, from articulating with the squamosal and alisphenoid. In the Catarrhine monkeys, on the other hand, as also in man, the parietal does not reach the malar, there being an isthmus between the two bones formed by the articulation of the frontal with the alisphenoid.

SATURDAY, SEPTEMBER 3.

The Department did not meet.

MONDAY, SEPTEMBER 5.

1. *On the Homology of the Conario-hypophysial Tract, or of the so-called 'Pineal' and 'Pituitary Glands.' By* Professor R. OWEN, *M.D., C.B., F.R.S.*

The author, referring to the latest contributions to the subjects of his paper, remarked that they bore upon the functions of the so-termed glands. Professor Sapolini, in his work 'L'aire de la Selle Turcique' (8vo., 1880), concludes that the 'pituitary gland secretes the fluid of the ventricles of the brain;' Professor Ed. Vom Beneden, in reference to the supposed pituitary gland in Ascidians, regards it as their renal excretory organ ('Archives de Biologie,' 8vo., 1881).

In pursuance of his aim, which was homological, Professor Owen traced the modifications of the pineal and pituitary bodies and connecting parts from man down to the lowest fishes possessing a brain; and noted the progressive increased relative size and retention of tubular structure of the tract including the so-called 'pituitary gland,' 'infundibulum,' 'third ventricle,' and 'pineal gland,' as the series descended; and he noted the further extension of the pineal part of the tract, beyond the brain, to its perforation of the cranium, leaving the so-called 'foramen parietale' or cranial 'navel,' in some existing and in many extinct *Reptilia.* These phenomena were then tested and compared with concomitant phases in the development of the Vertebrate, especially the Mammalian, embryo. It was shown, as had been noted by previous embryologists, that, prior to the permanent anterior outlet of the digestive sac, a production from such sac extended to the large cerebral vesicle subsequently reduced to a 'third ventricle,' whence the hollow tract was continued onward to the epithelial covering of the brain, by which it was closed. The lower, pharyngeal, beginning of this tract also became closed and modified, as the 'pituitary body': the upper continuation became modified, and in higher Vertebrates closed, as the 'pineal body'; but the intermediate portion of the tract retained its primitive hollow condition as the 'third ventricle' and 'infundibulum.' The 'sella turcica' in Mammals, like the 'foramen parietale' in cold-blooded Vertebrates, were modifications in the skeleton of parts of the primitive 'conario-hypophysial tract.' This tract, under all its modifications, divided, or marked vertically, the division between the 'cerebrum' and the 'optic lobes,' or divided the 'fore-brain' from the 'hind-brain.'

The author next proceeded to point out the homologies of the parts of the 'neural axis' in Invertebrates with those in Vertebrates.

The so-called 'supra-œsophageal ganglion or ganglions' in the former were homologous with the 'cerebrum or cerebral hemispheres' in the latter. The so-called 'subœsophageal masses' in Invertebrates answered to the mes- and ep- encephalic masses in Vertebrates. The neural chords and ganglions continued therefrom in Invertebrates answered to or were homologous with the myelon or spinal chord of Vertebrates, in which the ganglionic structure was more or less concealed, save in some fishes, by superadded neural substances.

Now, the 'supra-œsophageal mass,' or 'fore-brain,' in Invertebrates was divided from the 'sub-œsophageal masses,' or 'hind-brain,' by the production of a tubular portion of the fore part of the primarily closed alimentary cavity; which, extending between those parts of the neural axis, opened upon the surface of the head so attained, and there established the permanent 'mouth'; the tubular extension similarly retaining its functional or œsophageal relations with the alimentary cavity. The neural chords connecting the so separated fore-brain from the hind-brain, traversed the sides of this gullet; as the chords, or crura, proceeding to expand into the fore-brain of Vertebrates, traverse the sides or walls of that persistent part of the conario-hypophysial tract, known, in Anthropotomy, as the 'third ventricle.' The large relative size of the embryonal brain-vesicle, in this relation, is significative of the homology of the parts extending therefrom.

Passing, next, to the consideration of the characters which had been held to determine the 'back' and 'belly' of an animal, the author cited 'colour,' the relative position of the body of air-breathers to the ground they stood or moved upon,' and the criterion which Cuvier adopted to determine these aspects in the notable controversy with Geoffroy St. Hilaire, in 1830. That criterion was the 'cerebrum' in Vertebrates, and its homologue, the 'supra-œsophageal ganglion,' in Invertebrates. Cuvier exclusively applied the term 'brain' (*cerveau*) to this part of the cerebral centres; moreover, he expressly rejects the homology of the spinal chord of Vertebrates with the ganglionic chords of the body in Invertebrates.

In an enlarged copy of the diagram by which Cuvier illustrated his position, the author pointed out the grounds on which the great Comparative Anatomist concluded that, however his opponent might turn about his articulate or molluscous subject, the so-called 'brain' would be on opposite sides of the alimentary canal.

Now, to reconcile this difference it only needs to add to Cuvier's diagram of the brain of the mammal the conario-hypophysial tract; and, if the facts and deductions in the present paper were allowed to be valid, the actual difference would lie in the atrophy of the embryonal homologue of the Invertebrate gullet and mouth in the Vertebrates, and the establishment in them of a new entry to the alimentary cavity. In the Vertebrate embryo this anterior entry makes its first appearance as a capacious branchial or water-breathing organ, and traces of this destination are determinable in the higher Vertebrates, in which the respiratory function is, ultimately, otherwise located and is performed in relation to an aërial medium.

Returning to the criterions of the dorsal and ventral aspects of the animal body, the author, with, he believed, all fellow-labourers in Homological Anatomy, maintained that the ganglionic body-chord in Invertebrates did answer to the myelon of Vertebrates, and that, with the totality of the brain, the so-called 'neural axis' was determined. So determined, he held that its position was the true criterion of the dorsal or 'neural aspect' of the body, whether the animal moved with it next to or farthest from the ground, or neither the one nor the other, as in the human pedestrian. The part or aspect of the body opposite the neural one was characterised by the location of the centre, or chief centres, of the vascular system, and this had led Professor Owen, at the commencement of his anatomical teaching, to term it the 'hæmal aspect.'

Referring, finally, to the diagram of the Invertebrate and Vertebrate animals in corresponding positions, agreeably with the above criterion, the author showed that the so-called 'brain' (Cuvier), or the supra-œsophageal brain-mass, of Comparative Anatomy, was not above, but beneath, the mouth and gullet in Invertebrates, and that the 'sub-œsophageal mass' was above the mouth and gullet; also that the reverse relative positions were due to the atrophy of the primitive homologues of such entry in Vertebrates, and the substitution of another opening and conduit to the stomach; whereby these anterior openings and conduits are on the lower or 'hæmal' side of the cerebrum in Vertebrates, but on the upper or neural side of the 'cerebrum' or fore-brain in Invertebrates. Hence, the one division may be said to be 'hæmastomous,' the other division to be 'neurostomous.' But their common lan, or 'unity of composition,' was vindicated by the embryonal phenomena.

The paper was illustrated by drawings of the principal structures described, of which drawings enlarged diagrams were exhibited to the Section.

---

2. *On the Acetabulum of Animals in which the Ligamentum Teres is described as wanting.* *By* Professor STRUTHERS, *M.D.*

In man, the four-cornered bony recess, occupied by fat, in the floor of the acetabulum is exactly adapted to receive and cushion the ligamentum teres in the various movements of the hip-joint. In birds, the equivalent of the recess is a well-defined thin portion of the membrane which occupies the deficiency in the floor of the bony acetabulum. The modifications presented by the cotyloid notch, passage, and recess in mammals possessing the ligament, are, as in man, adaptations to the position, direction, and size of the ligament. In the hippopotamus the bony acetabulum seems incompatible with the existence of a ligamentum teres.

Among the few mammals in which the ligamentum teres is described as wanting, the author remarks on the parts in the ornithorhynchus, sloth, elephant, seal, and orang. The narrow Y-shaped recess in the ornithorhynchus suggests a relation to the triple line of meeting of the three primary bones in development. The condition in the ox, in which the ligament is present, suggests a similar relation. In the young human subject the triple line intersects the recess, but the pubes and ilium each bear only a small part of the recess.

In the three-toed sloth a recess of good length and breadth is seen in the bone. In the elephant the recess is present, but small in proportion to the size of the acetabulum. In the orang a good-sized and deep recess is present, running beyond the middle of the acetabulum, and as broad as the pubic or ischiatic parts of the cartilaginous crescent; the constricted part, leading from the notch, about half as broad. In the duckbill, sloth, elephant, and orang there is no mark on the femur to indicate the insertion of a ligamentum teres.

The author finds the ligamentum teres to be present in the Greenland seal, not free but projecting into the joint from the capsule. A dissection showing this was submitted to the Section. The ligament has the usual origin and is inserted into a well-marked notch in the margin of the head of the femur. A notch, not an enclosed pit, on the femur, for the insertion of the ligamentum teres, is seen in various mammals. In the seal, the acetabular recess is occupied by a fatty and synovial body, which also projects beyond the recess, and the projecting ligamentum teres lies against it.

---

3. *On the Correspondence between the Articulations of the Metacarpal and Metatarsal Bones in Man. By* Professor STRUTHERS, *M.D.*

On comparing the articulations of the bases of the metacarpal bones with those of the metatarsal bones, it will be found that, numerically and homologically, the correspondence is exact, bone for bone. Besides the great terminal facets for their carpal and tarsal supporting bases, and the lateral facets on both sides of the third and fourth, and on one side of the second and fifth, the second has two corner facets by which it articulates,—in the hand with the trapezium and os magnum, in the foot with the internal cuneiform and the external cuneiform; and the fourth has a corner facet by which it articulates,—in the hand with the os magnum, in the foot with the external cuneiform. Thus, including the phalanx, the numbers of the articulations of the five metacarpal and five metatarsal bones, from within outwards, are 2, 5, 4, 5, 3. Considering the very different functional adaptation of these homologous bones, this precise correspondence in their articulations is remarkable. Although the details of the articulations of each bone are fully given in the books on anatomy, the above correspondence has been overlooked, an illustration of how little human anatomy is usually, as yet, taught homologically, although thereby the study may be made both more interesting and more simple.

It is uncertain whether the variety occasionally seen of an articular facet between the first and second metatarsal bones is not a result of civilisation. The absence of such an articulation in the plantigrade human foot seems explicable by the original freedom of the great toe.

---

4. *On the Pronephros of Teleosteans and Ganoids. By* F. M. BALFOUR, *M.A., F.R.S.*

The author stated that the enlarged anterior part of the so-called kidney of Teleosteans and Ganoids, which is usually held to be the persistent pronephros or head-kidney, was in reality not part of the true kidney, but merely a great mass of lymphatic tissue. From this it follows that the very remarkable part of the larval kidney, known as the pronephros, does not persist in Ganoids and Teleosteans in the adult state; and since these two groups are the only ones in which this part of the larval kidney has been supposed to persist in the adult, it must now be held that there is no group known in which the pronephros lasts beyond larval life.

5. *On the Digastric Muscle, its Modifications and Functions.* *By* G. E. Dobson.

---

6. *On the Causes and Results of assumed Cycloidal Rotation in Arterial Red Discs.* *By* R. W. Woollcombe.

The author, having made some experiments with iron discs, given cycloidal rotation as projectiles (*vide* 'Proc. Royal Society,' March, 1862, and 'Journal of the Society of Arts,' Oct. 24, 1862, the latter being a paper read by author in Section G of the British Association, at Cambridge, in the same year), in pursuance of the subject of rotation in oblate bodies, has been struck by the oblate form of the red blood-disc, and advances the view that not only may the peculiar oblate form be given it by such rotation, during its development from (as already supposed) the amorphous white corpuscular matter, but that the red corpuscle is, until checked in the capillaries, impressed also with rotation imparted by two principal causes: one, momentary translatory hindrance from the concave side of a curve in an artery in passing it—such as the aortic, or the angles at the giving off of the intercostals; the other also given by the curves in the arteries, necessitating a velocity higher towards the distal than the proximal end of the radius of the curvature of the artery. These two causes tending to impart rotation to different discs in opposite directions, he conceives the direction of rotation to be of no importance to the disc, so that it does rotate. He relies on the natural law that 'rotation always tends to settle about the shortest diameter,' for the change to such diameter in the disc of any other rotation that might be set up, as, for instance, initially about a long diameter, especially in a body so oblate and symmetrical as the red disc. This natural law he illustrates by examples of every-day experience, as the rolling on their edges of irregularly-shaped leaves, or of scraps of paper on the ground before the wind, or the rolling about its shortest diameter of even an unsymmetrically-shaped stone when impelled or kicked on the ground; it being on the remarkable facility and permanence of such rotation, evidenced as well in the smallest as on the greatest scale in nature, that the author relies for the foundation of his hypothesis.

While the foregoing familiar instances exemplify the first of the two suggested ways in which rotation may be imparted, so the other way may be illustrated in the well-known experiment of Dr. Plateau with a rotating globule of oil. It remains to mention how, in the author's view, the rotation of the discs is left undisturbed until the capillaries are reached, and, lastly, of what use he assumes the alleged rotation to be.

He assumes that the contents of an artery are permeated by a similar electric state, and that from the known mutual repulsion amongst small bodies when in a similar electric condition, the corpuscles are thus virtually isolated, mechanically, from each other, also from the liquor sanguinis, and ordinarily (when not at the curves overcome by centrifugal force) isolated also from the serous coat of the artery; thus that the discs both translate and rotate presumably *in vacuo*. As to the uses of rotation, the author refers to the already recognised augmentation of one of the mechanical sources of heat from the temporary check to the *translative* movement of the discs in the capillaries, and points out that such heat would be supplemented by the necessary total arrest there of rotation in a disc, and that it would be but consistent with the recognised economy of forces in nature that where such supplementing can be done (as he argues it may be) without additional expenditure for either the initial force or for its conservation, and for an end so vital as that of heat, it is *à priori* more probable than less so that the movement of translation of the red arterial discs would be accompanied by the movement of rotation.

But the author also conceives this supplementing of heat to be not the only use of such rotation. The red disc carries the iron, and if there be magnetism in the system, as we know there is, then polarity in each disc is more conceivable in the view of rotation of the disc than of its not rotating.

It would be hard to conceive, for instance, of definite magnetic poles in the earth, were that much less oblate body than the disc without rotation. It is true the magnetic poles of the earth do not coincide with the axis of rotation; but it may be assumed that it is by the fixing effect of the rotation that the axis of the earth, omitting the nutation, is maintained at its given angle to the plane of the ecliptic, and that thus, though the magnetic poles are, of course, in oscillation, yet their direction as regards the fixed stars is a more determinate one than it would be if there was translation only of the earth without the fixing effect of rotation on one axis. Now, the gyroscope demonstrates that a plane of rotation cannot be interfered with without the result of determinate precessional movement—movements that, if there be rotation, are as likely and as certain to have an object in the microcosm of animal life as they could have in the economy of the celestial bodies, and, it may be added, as they must in any case have when they are but links in a chain of evolution.

The author remarks that while the general course of the arteries is direct and but little curved, the parts where we do find curves are mostly in proximity to special organs and in localities where it may be assumed that that high function of the arterial disc—the due stimulation of nerve-tissue—would be in stronger request than in parts such as the ordinary muscular tissue, where there was to be fulfilled a function less vital.

This sudden curve or angle of an artery or its spirality would, judging from what is seen in the gyroscope, cause, in the case of the simple curve or angle, a renewed, though it might be a reversed, rotation; and, in the case of the spiral artery, a precessional movement in the rotating disc, to which, the author repeats, he attaches especial consequence—a view that is unavoidable to him when he sees in the gyroscope, as one of its phenomena, the partial support against gravitation of the rotating disc and enclosing ring.

To sum up the conclusions of the author: 1st, rotation imparted by at least two different methods; 2ndly, rotation preserved from hindrance by repulsion due to a similar electric condition; 3rdly, rotation utilised in capillaries by its arrest there supplementing the heat due to checked translative motion of discs; 4thly, magnetic polarity of iron in discs more defined in direction by plane of rotation of disc being by the rotation more or less fixed; 5thly, special organs having notably curved or helicine arteries, the former adding to the velocity of rotation, and the helicine inducing precessional movement.

---

7. *Observations on the Incubation of the Indian Python* (Python molurus). *By* W. A. Forbes, *B.A.*

The only two previously recorded instances of the incubation of their eggs by female Pythons in captivity are those recorded by Valenciennes ('Comptes Rendus,' 1841, xiii. pp. 126–133), and Sclater ('P.Z.S.' 1862, pp. 365–368), for *P. bivittatus* and *P. sebæ* respectively. During the summer of 1881 a female of *Python molurus,* about 12 feet long, which was kept in the same cage in the reptile-house in the Zoological Society's Gardens as two other Pythons of the opposite sex, one being of the same species, the other *P. bivittatus,* laid about fifteen eggs, on which she sat steadily for about six weeks, in exactly the same manner as in the two instances mentioned above. At the termination of that period, as the eggs were decomposing and obviously bad, they were removed; some, at least, were fertilised, an embryo about 11½ inches long having been extracted from one.

With the kind aid of Mr. Zambra, of the well-known firm of Negretti & Zambra, who not only had special thermometers of the most approved kind constructed for this occasion, but also regularly attended himself to help in the observations, a series of observations, about two hundred in number, were taken at regular intervals of 48 or 72 hours, to ascertain the temperature of the sitting female, as compared with that of the non-incubating male, kept next door under nearly identical conditions of temperature and moisture. The result of these shows that, whereas the temperature of the male, whether taken on the surface or between the folds of the coiled-up body, varied very much as the temperature of the air in the cage, the curves falling or rising with it; that of the female, taken in the same way, was much more constant, particularly of the body between the folds. Not only so, but the average temperature of the female was much higher, the temperatures for the two sexes being respectively 86·7° F. and 89·75° F. between the folds, and on the surface 82·5° F. and 84·4° F., giving differences of 3·05° and 1·9° in favour of the female. In no case did the temperature of the male, taken between the folds, exceed that of the female; and in most cases there was a marked excess in that of the female, the average in one set of observations being as much as 7·6°. In no case was any such difference as 20·0°, like that recorded by Sclater, found. The highest temperature observed in the female was 92·8°; the highest observed by Valenciennes was 106·7°, or 14·0° higher. The greatest difference between the surface of the snake and that of the air in the cage observed was 9·6° F.

No such decline in temperature from the commencement to the end of incubation as was observed by Valenciennes could be made out in the present case. The maxima were attained when the temperature of the surrounding air was also at its highest, the range of the between-folds temperature being 6° (85·5° to 91·5°).

---

8. *On the Effect of the Voltaic Current on the Elimination of Sugar.* *By* W. H. STONE, *M.B., F.R.C.P.*

The suggestion of employing electricity in the form of a constant current in cases of glycosuria appears to date from the year 1861, on September 2 of which year M. Mariano Semmola read a paper before the French Académie des Sciences, recorded in the 'Comptes Rendus' of that date. He states his views as to the causation of the disease at considerable length in twenty-one propositions, referring to a previous paper brought before the same society six years earlier. Generally he attributes its occurrence either to exaggerated glycogenic action of the liver, or to default of respiratory oxidation. The distinction between these two forms, he thinks, can be made out by the permanence or the transient nature of the phenomenon and by the large or small quantity of sugar excreted. Where glycosuria accompanies disease of the nervous system, the series of symptoms is of a double nature. The first follows convulsive affections, such as epilepsy and hysteria; it is usually of short duration and evanescent; the second, which accompanies organic cerebral disease, must be looked on as a glycogenic stimulation of the fourth ventricle, and persists as long as the brain-disease itself, developing in direct ratio to the proximity of the brain-lesion to the roots of the pneumogastric nerve. A more or less definite congestion of the floor of the fourth ventricle he considers to be the pathological condition constantly observed in diabetic patients. The action of electricity seems to point to the disease having begun in an essential neurosis, which would offer a reasonable chance of cure. This view is strengthened by the fact that when diabetic patients are not carried off by tuberculosis, the cause of death is usually some nervous crisis, such as epilepsy or dyspnœa, due to apoplexy of the pons varolii. In his fifteenth and following propositions M. Semmola states that stimulation of the pneumogastric nerve by a direct current of sufficient force constantly produces a diminution in the quantity of sugar eliminated, and sometimes in the bulk of the secretion itself. These effects are passing, and only last from five to ten hours. Occasionally, however, they are more durable, and may amount to organic cure. He gives a case of a girl, aged 17, who became diabetic and amaurotic at the same time from a fright, and who recovered under galvanism. Electricity he considers not only a valuable therapeutical agent in such cases, but also useful in diagnosis, as a means of distinguishing between an idiopathic neurosis and one symptomatic of cerebral lesion.

The merit of this somewhat forgotten memoir consists not only in the clearness of the issues it raises, but also in the important distinction between neurotic and organic glycosuria, which must have struck every independent observer. The clear establishment of such a difference also goes far to explain the very variable results of treatment in this most intractable disease, and the want of success which has attended the labours of conscientious observers. It may be worth while to put on record a case which, although it terminated fatally, presents many points of physiological interest.

A. B. stated that for the last ten or twelve years he had suffered from bronchitis in the winter, but had never had hæmoptysis. The present illness, dated from two years ago, when he noticed frequent micturition, with increased quantity, and very ravenous appetite. These symptoms were accompanied by much loss of flesh, thirst, and coldness of the extremities. He stated that the urinary secretion averaged five or six pints daily, but had risen to nine pints. It tasted sweet at times, and at others bitter; in the latter case being very dark in colour. He knew of no cause for the illness, and entirely denied any fright, mental shock, or anxiety.

He was an intelligent man, by trade a surgical instrument maker, a fact which was of service in the use of galvanism. The skin was dry and rough; the eyesight dim, with occasional double vision. The pulse 68, rather weak. The heart-sounds were normal. The chest showed the usual signs of emphysema, with effacement of the cardiac dulness. The liver was, for the same reason, somewhat pushed downwards, but not enlarged, tender, or altered in resistance. The tongue was clean. The urine amounted to 73 oz., with a sp. gr. of 1·040. The temperature was throughout slightly subnormal, 97°–98°.

He was in the habit of taking crude opium in 2-gr. doses, twice or thrice daily, and at first expressed a strong craving for the drug. He was ordered codeia gr. ij, ter die, which gave him considerable relief and enabled him, of his own accord, to discontinue the opium. His chief complaint at this time was of failing eyesight.

The ophthalmoscope gave negative results, and there was no sign of cataract. There was well-marked central scotoma to colours, and the case resembled tobacco amblyopia, possibly accelerated by ill-health. During the first week the urine averaged 84 oz. daily, and contained, on quantitative examination, about 5 oz. of sugar. The treatment consisted solely of the codeia named above, which was afterwards replaced by a lemonade made with acid phosph. dil. sweetened with glycerine, and flavoured with lemons.

The improvement noted at first was not maintained, and the codeia was resumed, but the quantity of urine rose to 102 oz., to 139 oz., and ultimately to 150 oz. with a specific gravity of 1·040. The falling off in condition was so obvious that the lungs were again carefully examined, with a view to detect signs of latent phthisis, which were not, however, found.

He remained very ill during the month, and his weight sank to 8 st. 2½ lb. The urine was 160 oz., and shortly after it rose to the highest quantity recorded, viz. 170 oz., with an occasional sp. gr. of 1·045.

Seeing the threatening nature of the symptoms and the total ineffectuality of treatment, the use of the continued current to the head was suggested. It was decided to employ an ascending current from the nape of the neck to the forehead; the negative pole being placed in the former region, the positive in the latter. The current was of 1,500 micro-vebers in strength, and was at first continued for seven minutes. It gave him no uneasiness, and he thought himself temporarily better after it. It was from the first obvious that the action of electricity in a case of depraved nutrition, probably due to disorder of the organic nervous centre, should not be merely stimulant and occasional, but catalytic and constant. The patient himself was therefore entrusted with a powerful bichromate battery of thirty cells, and directed to use the strongest current he could bear with comfort, as above described, twice or thrice a day. All kinds of mechanical contact-makers and commutators were discarded, and the battery, instead of being screwed up in a French-polished box, was ranged in three sets of ten cells on the ward table. A simple binding-screw was attached to the required cell. It was thus easy to see what was being done, and impossible to err as to the real direction of the current. On electrical measurement, the strongest current he could bear, from nape to forehead, was found to be one of 10,000 micro-vebers. But a more moderate current of 1,800 micro-vebers was begun with and increased to 2,000 micro-vebers; it seemed to answer all purposes. The patient himself entered heartily into the treatment, and from the first declared himself better. The earliest symptom to amend was the eyesight, and the pinched expression of the face, which soon disappeared, with rapid recovery of flesh, amounting to 4 lbs. within a few weeks.

On December 6 the urine measured 80 oz., of sp. gr. 1·040. The thirst was less. He did not require opium, though he still took the codeia thrice daily in 2-gr. doses. The note taken on that day says: 'Patient uses 14 cells of the bichromate battery; is very much better.' The improvement was maintained until December 23, when some digestive disturbance occurred. On that day the quantity of water was 74 oz.

On the 27th the sp. gr. was found to be 1·038, the quantity 68 oz. On fermentation the sp. gr. only sank to 1·026, indicating a reduction of sugar excreted from 5 to about 2 oz. daily.

On January 7 the urine was quantitatively tested, in consequence of a severe relapse accompanied by febrile symptoms, which had necessitated the omission of the electricity. It was of sp. gr. 1·042, containing sugar 8·00 and urea 0·97 per cent., with a trace of albumen. It had sunk in quantity to under 50 oz. daily. The febrile access proved to be due to abscess.

On the 13th the quantity of urine rose again to 100 oz. Directly he could leave his bed he recommenced the use of the battery with the greatest ardour, from a conviction that it was of service to him. He was now able to bear a current of 10,000 micro-vebers from thirty-two of the bichromate cells abovementioned.

On the 22nd the quantity of urine was 58 oz. It continued at a comparatively reduced standard until February 9, on which day a large carbuncular boil began to form at the back of the neck, where the negative pole of the battery had been applied. The use of galvanism was then finally discontinued. The patient became much worse, restless, semi-comatose, with raw excoriated tongue, unable to take food or stimulants. The quantity of urine rose to 110 and 120 oz. The temperature remained at 98·6° Fahr. In this condition he remained until February 21, when it sank to 96·2°. On the following day he died. The pons varolii and medulla oblongata, on examination by Dr. Dickinson, showed enlargement, by erosion, of the peri-vascular canals in the lower part of the medulla near its centre, in the olivary body, in the upper part of the medulla, close to the floor of the fourth ventricle, and in the anterior part of the pons between the roots of the crura cerebri. In the two latter positions, both of which were in or close to the median plane, minute collections of brown matter were to be seen, external to the vessels, which consisted of blood-corpuscles apparently extruded during life.

The above brief notes are not intended to represent the whole bearings of a subject which cannot but be considered of importance. All details of a medical character have been excluded; but it has occurred to the author that sufficient facts of a purely physiological bearing remain, which may deserve the attention of the Section.

After the recent valuable researches of Mr. Gore in electrical osmose and diffusion, the statement of M. Semmola made twenty years ago, confirmed as it is by the above case, deserves careful reconsideration. The chemical effects of the galvanic current employed in its continuous form, undoubtedly require development, in opposition to the purely stimulant action on nerve and muscle of the induced current. The fact of a definite polarisation of the tissues included in a galvanic circuit, leading to a reverse current of a secondary character, has been shown both by Cyon of St. Petersburg, and by Onimus of Paris. It would almost seem, in this instance, as if an inhibitory alteration of osmose could be transmitted downwards from the governing centre, under the catalytic influence of the voltaic current, to the secreting organ at its peripheral extremity.

---

9. *On the Structure and Homologies of the Suspensory Ligament of the Fetlock in the Horse, Ass, Ox, Sheep, and Camel. By* D. J. CUNNINGHAM, *M.D., F.R.S.E.*

Section E.—GEOGRAPHY.

President of the Section—Sir J. D. Hooker, K.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S., F.G.S., F.R.G.S.

THURSDAY, SEPTEMBER 1.

The President delivered the following Address:—

On Geographical Distribution.

It has been suggested that a leading feature of the sectional addresses to be delivered on the occasion of this, the fiftieth anniversary of the meetings of the British Association, should be a review of the progress made during the last half-century in the branches of knowledge which the Sections respectively represent.

It has further been arranged that, at so auspicious an epoch, the Sections should, when possible, be presided over by past Presidents of the Association. This has resulted in almost every sectional chair being occupied by a President eminent as a cultivator of the science with which his Section will be engaged, though not the one I have the honour of filling, which, from the fact of there being no professed geographer amongst the surviving past Presidents, has been confided to an amateur.

Under these circumstances I should be untrue to myself and to you, if I presumed to address you as one conversant with geography in any extended signification of the word, or if I attempted to deal with that important and attractive branch of it, topographical discovery, which claims more or less exclusively the time and attention of the geographers of this country. It is more fitting for me, and more in keeping with the objects of this Association, that I be allowed to discourse before you on one of the many branches of science the pursuit of which is involved in the higher aims of geographers, and which, as we are informed by an accomplished cultivator of the science, are integral portions of scientific geography.[1] Of these none is more important than that of the distribution of animals and plants, which further recommends itself to you on this occasion from being a subject that owes its great progress during the last half-century as much to the theories advanced by celebrated voyagers and travellers as to their observations and collections.

Before, however, I proceed to offer you a sketch of the progress made during the lifetime of the Association in this one branch, I must digress to remind you, however briefly, of the even greater advances made in others, in many cases through the direct or indirect instrumentality of the Association itself, acting in concert with the Royal and with the Royal Geographical Societies.

In topography the knowledge obtained during this half-century has been unprecedentedly great. The veil has been withdrawn from the sources of the Nile, and the lake systems of Central Africa have been approximately localised and outlined. Australia, never previously traversed, has been crossed and recrossed in various directions. New Guinea has had its coasts surveyed, and its previously utterly unknown interior has been here and there visited. The topography of Western China and

[1] Major-General Strachey, in a lecture delivered before the Royal Geographical Society (*Proceedings*, vol. xxxi. p. 179, 1877) discusses with just appreciation and admirable clearness, the interdependence of the sciences which enter into the study and aims of scientific geography, and which he enumerates under fourteen heads. This lecture contains the ablest review of the subject known to me. It might very well be entitled 'The whole duty of the Geographer.' Every traveller's outfit should include a copy of it, and one should accompany every prize given by the Geographical Society to students for proficiency in geographical knowledge.

Central Asia, which had been sealed books since the days of Marco Polo, has been explored in many quarters. The elevations of the highest mountains of both hemispheres have been accurately determined, and themselves ascended to heights never before attained; and the upper regions of the air have been ballooned to the extreme limit beyond which the life-sustaining organs of the human frame can no longer perform their functions. In hydrography the depths of the great oceans have been sounded, their shores mapped, and their physical and natural history explored from the Equator to beyond both polar circles. In the Arctic regions the highest hitherto attained latitudes have been reached; Greenland has been proved to be an island; and an archipelago has been discovered nearer to the Pole than any other land. In the Antarctic regions a new continent has been added to our maps, crowned with one of the loftiest known active volcanoes, and the Antarctic ocean has been twice traversed to the 79th parallel. Nor have some of the negative results of modern exploration been less important, for the Mountains of the Moon and many lesser chains have been expunged from our maps, and there are no longer believers in the inland sea of Australia or in the open ocean of the Arctic pole. Of these and many others of the geographical discoveries of the last half-century full accounts will be laid before you, prepared for this Section by able geographers; of whom Mr. Markham will contribute Arctic discovery; Sir Richard Temple, Asiatic; Lieut.-Col. Sir James Grant and Mr. H. Waller, African; Mr. Moseley, Australian; Mr. Trelawny Saunders, Syrian (including the Holy Land); the Hydrographer of the Admiralty will undertake the great oceans, and Mr. F. Galton will discuss the improvements effected in the instruments, appliances, and methods of investigation employed in geographical researches.

Of other branches of science which are auxiliary to scientific geography, the majority will be treated of in the Sections of the Association to which they belong; but there are a few which I must not, in justice to the geographers who have so largely contributed to their advance, leave unnoticed.

Such is terrestrial magnetism [1] which had as its first investigators two of our earliest voyagers, the ill-fated Hudson and Halley, who determined the magnetic dip in the North polar and tropical regions respectively. Theirs were the precursors of a long series of scientific expeditions, during which the dipping needle was carried almost from Pole to Pole, and which culminated in the establishment, mainly under the auspices of this Association, of the magnetic survey of Great Britain, of fixed magnetic observatories in all quarters of the globe, and of the Antarctic expedition of Sir James Ross, who, since the foundation of the Association, planted the dipping needle over the northern Magnetic Pole, and carried it within 200 miles of the southern one.

Nor is the geography of this half-century less indebted to physicists, geologists, and naturalists. It is to a most learned traveller and naturalist, Von Baer, that the conception is due that the westward deflection of all the South Russian rivers is caused by the revolution of the globe on its axis.[2] It was a geologist, Ramsay, who explained the formation of so many lake-beds in mountain regions by the gouging action of glaciers. It was a physicist and mountaineer, Tyndall, who discovered those properties of ice upon which the formation and movement of glaciers depend. The greatest of naturalist-voyagers, Darwin, within the same half-century has produced the true theory of coral reefs and atolls, showed the relations between volcanic islands and the rising and sinking of the bottom of the ocean, and proved that along a coast-line of 2,480 miles the southern part of the continent of South America has been gradually elevated from the sea-level to 600 feet above it. Within almost the same period Poulett Scrope and Lyell have revolutionised the theory of the formation of volcanic mountains, showing that these are not the long-taught upheavals of the crust of the earth, but are heaped up deposits from volcanic vents, and they have largely contributed to the abandon-

[1] The subject of an able lecture 'On the Magnetism of the Earth,' delivered before the Royal Geographical Society by the Hydrographer of the Admiralty (*Proceedings*, vol. xxi. p. 20, 1876).

[2] Von Baer, 'Ueber ein allgemeines Gesetz in der Gestaltung der Flussbetten,' *St. Petersb. Bull. Sc.* ii. (1860).

ment of the venerable theory that mountain chains are sudden up-thrusts. Within the same period, the theory of the great oceans having occupied their present positions on the globe from very early geological times was first propounded by Dana,[1] the companion of Wilkes in his expedition round the world, and is supported by Darwin and by Wallace.

In Meteorology the advance is no less attributable to the labours of voyagers and travellers. The establishment of the Meteorological office is due to the energy and perseverance of a great navigator, the late Admiral Fitzroy.

Another domain of knowledge that claims the strongest sympathies of the geographer is Anthropology. It is only within the last quarter of a century that the study of man under his physical aspect has been recognised as a distinct branch of science, and represented by a flourishing society, and by annual international congresses.

I must not conclude this notice without a passing tribute to a department of Geography that has occupied the attention of too few of its cultivators. I mean that of literary research. Nevertheless, in this too the progress has been great; and I need only mention the publications of the Hakluyt Society, and two works of prodigious learning and the greatest value, 'The Book of Marco Polo, the Venetian,'[2] and 'A History of Ancient Geography,'[3] to prove to you that one need not to travel to new lands to be a profound and sagacious geographer.

I have asked you to accept the geographical distribution of organic beings as the subject which I have chosen for this address. It is the branch with which I am most familiar; it illustrates extremely well the interdependence of those sciences which the geographer should study, and as I have before observed, its progress has been in the main due to the labours of voyagers and travellers.

In the science of distribution, Botany took the lead. Humboldt, in one of his essays,[4] says that the germ of it is to be found in an idea of Tournefort, developed by Linnæus. Tournefort was a Frenchman of great learning, and, moreover, a great traveller. He was sent by the King of France in 1700 to explore the islands of Greece and mountains of Armenia, in the interests of the Jardin des Plantes, and his published narrative is full of valuable matter on the people, antiquities, and natural productions of the countries he visited. The idea attributed to him by Humboldt[5] is, that in ascending mountains we meet successively with vegetations that represent those of successively higher latitudes; upon which Humboldt observes: 'Il ne fallut pas une grande sagacité pour observer que sur les pentes des hautes montagnes de l'Arménie, des végétaux des différentes latitudes se suivent comme les climats superposés l'un sur les autres;' but he goes on to remark, 'cette idée de Tournefort developpée par Linné dans deux dissertations intéressantes (Stationes et Coloniæ Plantarum), renferment cependant le germe de la Géographie Botanique.' Tournefort's idea was, however, an advanced one for the age he lived in, and should not be judged by the light of the knowledge of a succeeding century. He had no experience of other latitudes than the few intervening between Paris and the Levant. Humboldt himself did not suspect the whole bearing of the idea on the principles of geographical distribution, and that the parallelism between the floras of mountains and of latitudes was the result of community of descent of the plants composing the floras, nor that it was brought about by physical causes. The idea of the early part of the eighteenth century is, when rightly understood, found to be the forerunner of the matured knowledge of the middle of the nineteenth.

The labours of Linnæus, himself a traveller, whose narratives give him

[1] Dana in *American Journal of Science*, Ser. 2, Vol. iii. p. 352 (1847), and various later publications.

[2] By Colonel Henry Yule, C.B. (ed. 1, 1871; ed. 2, 1875).

[3] By S. H. Bunbury (1879).

[4] 'Sur les lois que l'on observe dans le distribution des formes végétales' (*Mémoire lu à l'Institut de France*, January 29, 1816).

[5] I have been unable to find any such idea expressed in Tournefort's works. Edward Forbes, however, also attributes the idea to Tournefort (*Memoirs of the Geological Survey*, vol. i. p. 351).

high rank as such, paved the way to a correct study of botanical geography. Before his time little or no attention was paid to the topography of plants, and he was the first to distinguish, to lay down rules, and to supply models for these two important elements in their life-history—namely, their habitats or topographical localisation, and their stations, or the physical nature of their habitats. In his 'Stationes Plantarum,'[1] Linnæus defines with precision twenty-four stations characterised by soil, moisture, exposure, climate, &c., which, with comparatively slight modifications and improvements, have been adopted by all subsequent authorities. Nor, indeed, was any marked advance in this subject made, till geological observation and chemical analysis supplemented its shortcomings. In his essay 'De coloniis plantarum,' published fourteen years after the 'Stationes,'[2] he says, 'Qui veram cunque et solidam plantarum scientiam aucupatur, patriam ipsarum ac sedem cujusque propriam haud sane ignorabit,' and he proceeds to give an outline of the distribution of certain plants on the globe, according to climate, latitude, &c., and to indicate their means of transport by winds, birds, and other agencies. India (meaning the tropics of both worlds) he characterises as the region of palms; the temperate latitudes, of herbaceous plants; the northern, of mosses, algæ, and coniferæ; and America, of ferns;—thus preparing the way for the next great generaliser in the field.[3]

This was the most accomplished and prolific of modern travellers, Humboldt, who made Botany a chief pursuit during all his journeys, and who seems, indeed, to have been devoted to it from a very early age. His first work was a botanical one, the 'Flora Friburgensis,' and we have it on his own authority that three years before its publication, when he was only just of age (in 1790) he communicated to his friend, G. Förster, the companion of Cook in his second voyage, a sketch of a geography of plants. It was not, however, till his return from America that his first essay on Botanical Geography[4] appeared, which at once gave him a very high position as a philosophical naturalist. Up to the period of its appearance there had been nothing of the kind to compare with it for the wealth of facts, botanical, meteorological, and hypsometrical, derived from his own observations, from the works of travellers and naturalists, and from personal communication with his contemporaries, all correlated with consummate skill and discussed with that lucidity of exposition of which he was a master. The great feature of this essay is the exactness of the methods employed for estimating the conditions under which species, genera, and families are grouped geographically, and the precision with which they are expressed.

This was succeeded in 1815, and subsequently, by four other essays on the same subject. Of these the most valuable is the 'Prolegomena,'[5] in which he

[1] *Amœnitates Academicæ*, vol. iv. p. 64, 1754.

[2] Ibid. vol. viii. p. 1, 1768.

[3] Between the dates of the writings of Linnæus and Humboldt, two noteable works on geographical distribution appeared. One by Frid. Stromeyer (*Commentatio inauguralis sistens Historiæ Vegetabilium Geographicæ specimen*, Göttingen, 1800), is an excellent syllabus of the points to be attended to in the study of distribution, but without examples; the other is a too general work by Zimmermann, entitled, *Specimen Zoologiæ Geographicæ, Quadrupedum Domicilia et Migrationes sistens*, Lugd. Bat. 1777, which he followed by *Geographische Geschichte des Menschen und der allgemein verbreiteten vierfüssigen Thiere, nebst einer hieher gehörigen Zoologischen Weltcharte*, Leipsic, 1778–1783.

[4] 'Essai sur la Géographie des Plantes,' par A. de Humboldt et Aimé Bonpland; rédigee, par A. de Humboldt, *Lu à la Classe des Sc. Phys. et Math. de l'Institut Nationale*, 17 Nivôse de l'An 13, 1805.

[5] 'De Distributione Geographica plantarum secundum cœli temperiem et altitudinem Montium, Prolegomena.' This appeared in quarto in the first volume of the *Nova Genera et Species Plantarum*, in 1815, and separately in an octavo form in 1817. Humboldt's other works on geographical distribution are *Notationes ad Geographiam Plantarum spectantes*, 1815; *Ansichten der Natur*, 1808, and Ed. 2, 1827; *Nouvelles Recherches sur les lois que l'on observe dans la Distribution des formes végétales* (1816); and an article with a similar title in the *Dictionaire des Sciences Naturelles*, vol. xviii. p. 422, 1820.

dwells at length on the value of numerical data, and explains his 'Arithmeticæ botanices' which consists in determining the proportion which the species of certain large families or groups of families bear to the whole number of species composing the floras in advancing from the Equator to the Poles, and in ascending mountains. Some kinds of plants, he says, increase in numbers relatively to others in proceeding from the Equator to the Poles, as ferns, grasses, amentiferous trees, &c.; others decrease, as Rubiaceæ, Malvaceæ, Compositæ, &c.; whilst others still, as Labiatæ, Cruciferæ, &c., find their maximum in temperate regions, and decrease in both directions. He adds that it is only by accurately measuring this decrease or increase that laws can be established, when it is found that these present constant relations to parallels of temperature.[1] Furthermore, he says that in many cases the whole number of plants contained in any given region of the globe may be approximately determined by ascertaining the number of species of such families.

The importance of this method of analysing the vegetation of a country in researches in geographical botany is obvious, for it affords the most instructive method of setting forth the relations that exist between a flora and its geographical position and climatal conditions.

Humboldt's labours on the laws of distribution were not limited to floras, they included man and the lower animals, cultivated and domesticated, as well as native; they may not be works of the greatest originality, but they show remarkable powers of observation and reflection, astonishing industry, conscientious exactitude in the collection of data, and sagacity in the use of them: he is indisputably the founder of this department of geographical science.

No material advance was made towards improving the laws of geographical distribution[2] so long as it was believed that the continents and oceans had experienced no great changes of surface or of climate since the introduction of the existing assemblages of animals and plants. This belief in the comparative stability of the surface was first dispersed by Lyell, who showed that a fauna may be older than the land it inhabits. To this conclusion he was led by the study of the recent and later tertiary molluscs of Sicily, which he found had migrated into that land before its separation from the continent of Italy; just, he adds, as the plants and animals of the Phlegræan fields had colonised Monte Nuovo since that mountain was thrown up in the sixteenth century; whence, he goes on to say, we are brought to admit the curious result, that the fauna and flora of Val de Noto, and of some other mountain regions of Italy, are of higher antiquity than the country itself, having not only flourished before the lands were raised from the deep, but even before they were deposited beneath the waters.[3] The same idea occurred to Darwin who, alluding to the very few species of living quadrupeds which are altogether terrestrial in habit, that are common to Asia and America, and to these few being confined to the extreme frozen regions of the North, adds, 'We may safely look at this quarter (Behring's Straits), as the line of communication (now interrupted by the steady progress of geological change), by which the elephant, the ox, and the horse entered America, and peopled its wide extent.'[4]

The belief in the stability of climatal conditions during the lifetime of the existing assemblages of animals and plants was also dispelled by the discovery, throughout the northern temperate regions of the old and new worlds, of Arctic

[1] Humboldt's Isothermal lines and Laws of geographical distribution are obviously the twin results of the same researches, one physical the other biological.

[2] I do not hereby imply that no progress was made in the knowledge of the facts of distribution, for over and above many treatises on the distribution of the plants of local floras, there appeared, in 1816, Schouw's *Dissertatio de sedibus plantarum originariis*; which was followed in 1822 by his excellent *Grundtrack til el almendelig Plante-Geographie*, of which the German edition is entitled, *Grundzuge einer allgemeiner Pflanzengeographie.*

[3] *Principles of Geology*, ed. 3, vol. iii. p. 376, 1834.

[4] *Journal of Researches in Geology and Natural History, &c.*, p. 151, 1839.

and boreal plants on all their mountains, and of these fossilised on their low lands; discoveries which led to the recognition of the glacial period and glacial ocean.

The first and boldest attempt to press the results of geological and climatal changes into the service of botanical and zoological geography, was that of the late Edward Forbes, a naturalist of genius, who, like Tournefort, chose the Levant as the field for his early labours. In the year 1845, Forbes communicated a paper to the Natural History section of this Association, on the distribution of endemic plants, especially those of the British Islands, considered with regard to geological changes.[1] In this paper the British flora is considered to consist of assemblages of plants from five distinct sources, which, with the exception of one, immigrated during periods when the British Isles were united to the continent of Europe, and have remained more or less localised in England, in Scotland, or in Ireland. Of these he considered the Pyrenean assemblage, which is confined to the west of Ireland, to be the oldest, and to have immigrated after the eocene period, along a chain of now submerged mountains, that extended across the Atlantic from Spain to Ireland, and indeed formed the eastern boundary of an imaginary continent of pliocene age, which extended to the Azores Islands, and beyond them. This, the 'Atlantis' of speculative geologists, has long since been abandoned. The second assemblage is of plants characteristic of the South-West of France, which now prevail in Devon, Cornwall, and the Channel Islands; their immigration he assigns to a pliocene date, probably corresponding to the red crag. The third assemblage is of plants of the North-East of France, which abound in the chalk districts of the South-Eastern counties of England; their immigration is referred to the era of the mammaliferous crag. The fourth is of Alpine plants now found on the mountains of Scotland, Wales, and England; these were introduced mainly by floating ice from Scandinavia during the glacial period, when the greater part of the British Isles were submerged, its mountain tops forming part of a chain of islands in the glacial sea that extended to the coast of Norway; this was during the newer pliocene period. Lastly, the Germanic plants were introduced during the upheaval of the British Islands from the glacial ocean, and as the temperature was gradually increasing; these are spread over the whole islands, though more abundant on the eastern side. At the commencement of this immigration England was supposed to be continuous with the Germanic plains, from which it was subsequently severed by the formation of the English Channel. Also, at the commencement of this immigration Ireland was assumed to be continuous with England, to be early severed by the formation of the Irish Sea; which severance, by interrupting the migration of Germanic types, accounts for the absence of so many British animals in the sister island.

I have thus briefly related Forbes' views, to show how profoundly he was impressed with the belief that geographical and climatal conditions were the all-powerful controllers of the migrations of animals and plants. Forbes was the reformer of the science of geographical distribution.[2]

[1] *British Association Reports*, 1845, pt. ii. p. 67, and *Annals and Magazine of Natural History*, vol. xvi. p. 126. This the author followed by a much fuller exposition of the subject, which appeared in the *Memoirs of the Geological Survey of the United Kingdom*, vol. i. p. 336 (1846), entitled 'On the Connection between the distribution of the existing flora and fauna of the British Isles, and the geological changes which have affected their area, especially during the epoch of the northern drift.' After many years' interval I have re-read this Memoir with increased pleasure and profit. The stores of exact information which he collected concerning the plants, the animals, and the geology of Europe and North America, appear to me to be no less remarkable than the skill with which he correlated them and educed from the whole so many very original and in great part incontrovertible conclusions.

[2] I cannot dismiss the subject of the geography of the British flora without an allusion to the labours of Hewett Cottrell Watson, who, after a life devoted to the topography of British plants, was laid in the grave only a month ago. Watson was the first botanist who measured the altitudinal range of each species, and, by a rigidly statistical method, traced their distribution in every county, and grouped them according to their continental affinities, as well as by the physical conditions of their habitats.

Before the publication of the doctrine of the origin of species by variation and natural selection, all reasoning on their distribution was in subordination to the idea that these were permanent and special creations; just as, before it was shown that species were often older than the islands and mountains they inhabited, naturalists had to make their theories accord with the idea that all migration took place under existing conditions of land and sea. Hitherto the modes of dispersion of species, genera, and families, had been traced; but the origin of representative species, genera, and families, remained an enigma;[1] these could be explained only by the supposition that the localities where they occurred presented conditions so similar that they favoured the creation of similar organisms, which failed to account for representation occurring in the far more numerous cases where there is no discoverable similarity of physical conditions, and of their not occurring in places where the conditions are similar. Now under the theory of modification of species after migration and isolation, their representation in distant localities is only a question of time and changed physical conditions. In fact, as Darwin well sums up, all[2] the leading facts of distribution are clearly explicable under this theory; such as the multiplication of new forms; the importance of barriers in forming and separating zoological and botanical provinces; the concentration of related species in the same area; the linking together under different latitudes of the inhabitants of the plains and mountains, of the forests, marshes, and deserts, and the linking of these with the extinct beings which formerly inhabited the same areas; and the fact of different forms of life occurring in areas having nearly the same physical conditions.

With the establishment of the doctrine of the orderly evolution of species under known laws, I close this list of those recognised principles of the science of geographical distribution, which must guide all who enter upon its pursuit. As Humboldt was its founder, and Forbes its reformer, so we must regard Darwin as its latest and greatest lawgiver. With their example, and their conclusions to guide, advance becomes possible whenever discovery opens new paths, or study and reflection retraverse the old ones.

And it was not long before palæontology brought to the surface new data for the study of the present and past physical geography of the globe.

This was the discovery in Arctic latitudes of fossil plants whose existing representatives are to be found only in warm temperate ones. To Arctic travellers and voyagers this discovery is wholly due. Of these, I believe I am correct in saying that Sir John Richardson was the earliest, for he, in the year 1848, when descending the McKenzie river to the Polar Sea in search of the Franklin Expedition, found in lat. 65° N. beds of coal, besides shales, full of leaves of forest-trees belonging to such genera as the maple, poplar, taxodium, oak, &c. In the narrative of his journey,[3] Richardson mentions these fossils and figures some of them; and in a subsequent work[4] he speaks of them as 'leaves of deciduous trees belonging to genera which do not in the present day come so far north on the American continent by ten or twelve degrees of latitude.' This discovery was followed, in 1853, by the still more remarkable one, by Captain M'Clure and Sir Alexander Armstrong (during another search for Sir John Franklin), of pine-cones and acorns imbedded in the soil of Banksland, in lat. 75° N., at an elevation

[1] The representation of species Forbes alludes to as 'an accident . . . . which has hitherto not been accounted for.'—*Mem. Geol. Survey*, vol. i. p. 351.

[2] Of the many pre-Darwinian writers on distribution who advocated the Lamarkian doctrine of evolution, I am not aware of any who suggested that it would explain the existence of representative species, or indeed any other of the phenomena of distribution. Von Baer, however, in the very year of the publication of the first edition of the *Origin of Species*, expressed his conviction, chiefly grounded on the laws of geographical distribution, that forms now specifically distinct have descended from a single parent form. See *Origin of Species*, ed. 5, Historical Sketch, p. 23.

[3] *Boat Voyage through Rupert's Land and in the Arctic Sea*, vol. i. p. 186.

[4] *Polar Regions*, p. 289.

of 300 feet above the sea-level. And again in 1854, Dr. Lyall found extensive accumulations of similar fossils near Discoe in Greenland (lat. 70° N.), during the return of Sir Edward Belcher's searching expedition. Nor are these fossils confined to America: they have been found in Spitzbergen, in Siberia, and in many other localities within the Polar area as well as south of it, proving that forests of deciduous trees, in all respects like those of the existing forests of the warm temperate regions, approached to within ten degrees of the Pole. The first of these collections critically examined was Dr. Lyall's; it was communicated to Professor Heer of Zurich, the highest authority on the flora of the tertiary period, and described by him,[1] as were also subsequently all the other collections brought from the Arctic regions.[2]

The examination of these fossil leaves revealed the wonderful fact that, not only did they belong to genera of trees common to the forests of all the three northern continents, such as planes, beeches, ashes, maples, &c., but that they also included what are now extremely rare and even local genera, as sequoia, liquidamber, magnolia, tulip-trees, gingkos, &c., proving that the forests were of a more mixed character than any now existing. These results opened up a new channel for investigating the problem of distribution, and the first naturalist to enter it was a botanist, Dr. Asa Gray, who pursued it with brilliant results, embodied in a series of memoirs on the vegetation of the United States of America, of which my notice must be most brief.

When studying the collections of Japanese plants brought by the officers of Wilkes' expedition, Dr. Gray found cumulative evidence of the strong affinity between the flora of Eastern Asia and Eastern North America, to the exclusion of the western half of that continent; and also that Europe and Western Asia did not share in this affinity. But what especially attracted his attention was, that this affinity did not depend only on a few identical or representative genera but upon many endemic genera of exceptional character, and often consisting of only two almost identical species. This led to a rigorous comparison of those plants with the fossils from the Arctic regions whose affinities had been determined by Heer, and with others which had been meanwhile accumulating in the United States, and had been described by Lesquereux; and the result was what I may call an abridged outline history of the flora of North America in its relations to the physical geography of that country, from the cretaceous to the present time.

The latest researches which have materially advanced our knowledge of the laws of distribution are those of Prof. Blytt, of Christiania. His essay on 'the immigration of the Norwegian flora during alternately rainy and dry periods, has for its object to define and localise the various assemblages of plants of which that flora is composed, and to ascertain their mother-country and the sequence of their introduction. The problem is that of Prof. Forbes, which I have already described to you, only substituting Norway for the British Isles. Both these authors invoke the glacial period to account for the dispersion of Arctic plants, both deal with a rising land, both assume that immigration took place over land; but Prof. Blytt finds another and most powerful controlling agent, in alternating periods of greater moisture and comparative drought, of which the Norwegian peat-bogs afford ample proof. These bogs were formed during the rise of the land, as the cold of the glacial period declined. They are found at various heights above the sea in Norway; the most elevated of them are of course the oldest, and contain remains of the earliest immigrants. The lowest are the newest and contain remains of the latest introduced plants only. The proofs of the alternating wet and dry seasons rest on the fact, that the different layers of peat in each bog present widely different characters, contain the remains of different assemblages of plants, and these characters recur in the same order in all the bogs. First there is a layer of wet spongy peat, with the remains of bog-mosses and aquatic plants; this gradually passes upwards into a layer of dry soil containing the remains of many land plants,

[1] 'Ueber die von Dr. Lyall in Grönland entdeckten fossilen Pflanzen,' *Zürich Vierteljahrsschr.* vol. vii. p. 176 (1862).

[2] *Flora fossilis Arctica.*

and prostrate trunks of trees, showing that the country was forested. To this succeeds wet spongy peat as before, to be again covered with dry peaty soil and tree trunks, &c., and so on. From an examination of the plant-remains in these formations, Prof. Blytt draws the following conclusions:—

The Norwegian flora began with an immigration of Arctic plants during a dry period, evidence of which he finds in the presence of the remains of these beneath the lowest layer of peat. As the climate became warmer and the land rose, a rainy period set in, accompanied by an immigration of sub-arctic plants (juniper, mountain ash, aconites, &c.), which to a great extent replaced the Arctic flora, which is impatient of great wet. This was the period of the first peat-bog formation. It was followed by a dry period, during which the bogs gradually dried up; while, with the increasing warmth, deciduous trees and their accompanying herbaceous vegetation were introduced. The succeeding rainy season produced a second peat-formation, killing and burying the deciduous trees, the increasing warmth at the same time bringing in the Atlantic flora, characterised by the holly, foxglove, and other plants now confined in Norway to the rainy Atlantic coast. To this succeeded a third period of drought, when the bogs dried up and pine forests with their accompanying plants immigrated into Norway, to be in like manner destroyed and buried by bog earth during the next following rainy period; and it was during these last alternations that the subboreal plants now affecting the lowest south-eastern districts of Norway were introduced; and the sub-atlantic plants, the most southern of all the types, which are confined to the extreme south of the country.

It would be premature to regard all Prof. Blytt's recurrent periods as irrefragably established, or his correlations of these with the several floras as fully proved; but there is no doubt, I think, that he has brought forward a *vera causa* to account for the alternation of dry country with wet country plants in Norway, and one that must have both actively promoted the first introduction of these into that country and also influenced their subsequent localisation. It would strengthen Prof. Blytt's conclusions very much, if his alternating periods of rain and drought should be found to harmonise with Mr. Croll's recurrent astronomical periods, and with Mr. Geikie's fluctuations of temperature during the decline of the glacial epoch: so would also the finding in the bogs of Scotland a repetition of the conditions which obtain in those of Norway; and there are so very many points of resemblance in the physical geography and vegetation of these two countries, that I do not doubt a comparison of their peat-formations would yield most instructive results.

Thus far all the knowledge we have obtained of the agents controlling geographical distribution have been derived from observations and researches on northern animals and plants, recent and tertiary. Turning now to the southern hemisphere, the phenomena of distribution are much more difficult of explanation. Geographically speaking there is no Antarctic flora except a few lichens and seaweeds. The plants called Antarctic,[1] from their analogy with the Arctic, are very few in number, and nowhere cross 62° of south latitude. They are, in so far as they are endemic, confined to the southern islands of the great southern ocean, and the mountains of South Chili, Australia, Tasmania, and New Zealand; whilst the few non-endemic are species of the nearest continents, or are identical with temperate northern or with sub-arctic or even Arctic species. Like the Arctic flora, the Antarctic is a very uniform one round the globe, the same species, in many cases, especially the non-endemic, occurring on every island, though there are sometimes thousands of miles of ocean between the nearest of these. And, as many of the island plants reappear on the mountains above mentioned, far to the north of their island homes, it is inferred on these grounds, as well as on astronomical and geological, that there was a glacial period in the southern temperate zone as well as in the northern.

The south temperate flora is a fourfold one. South America, South Africa,

[1] For accounts of the Antarctic flora see the *Botany* of the Antarctic Expedition of Sir James Ross, where the relations of the floras of the southern hemisphere with the Antarctic are discussed in introductory chapters.

Australia, and New Zealand contain each an assemblage of plants differing more by far amongst themselves than do the floras of Europe, North Asia, and North America; they contain, in fact, few species in common, except the Antarctic ones that inhabit their mountains. These south temperate plants have their representative species and genera on the mountains of the tropics, each in their own meridian only, and there they meet immigrants from all latitudes of the northern hemisphere. Thus the plants of Fuegia extend northward along the Andes, ascending as they advance. Australian genera reappear on the lofty mountain of Kini-balu in Borneo; New Zealand ones on the mountains of New Caledonia; and the most interesting herbarium ever brought from Central Africa, that of Mr. Joseph Thomson, from the highlands of the lake districts, contains many of the endemic genera, and even species of the Cape of Good Hope. Nor does the northern representation of the south temperate flora cease within the tropics; it extends to the middle north temperate zone; Chilian genera reappearing in Mexico and California; South African in North Africa, in the Canary Islands, and even in Asia Minor[1]; and Australian in the Khasia Mountains of East Bengal, in East China and Japan.

So too there is a representation of genera in the southern temperate continents, feeble numerically, compared to what the north presents, but strong in other respects. This is shown by the families of Proteaceæ, Cycadeæ, and Restiaceæ, abounding in South Africa and Australia alone, though not a single species or even genus of these families is common to the two countries; by New Zealand, with a flora differing in almost every element from the Chilian, yet having a few species of both calceolaria and fuchsia, genera otherwise purely American; whilst as regards Australia and New Zealand, it is difficult to say which are the most puzzling—the contrasts, or the similarities, which their animal and vegetable productions present.

These features of the vegetation of the south temperate and Antarctic regions, though they simulate those of the north temperate and Arctic, may not originate from precisely similar causes. In the absence of such evidence as the fossil animals and plants of the North affords,[2] there is no proof that the Antarctic plants found on the south temperate alps, or the south temperate plants found in the mountains of the tropics, originated in the south; though this appears probable from the absence in the south of so many of the leading families of plants and animals of the north, no less than from the number of endemic forms the south contains. These considerations have favoured the speculation of the former existence, during a warmer period than the present, of a centre of creation in the Southern Ocean, in the form of either a continent or of an archipelago, from which both the Antarctic and Southern endemic forms radiated. I have myself suggested continental or insular extension[3] as a means of aiding that wide dispersion of species over the Southern Ocean, which it is difficult to explain without such intervention; and the discovery of beds of fossil trunks of trees in Kerguelen's Island, testifies to that place having enjoyed a warmer climate than its present one.

The rarity in the existing Archipelago (Kerguelen's Island, the Crozets, and Prince Edward's Island) of any of the endemic genera of the south temperate flora, or of representatives of them, is, however, an argument against such land, if

[1] Pelargonium Endlicherianum in the Taurus is a remarkable instance.

[2] The only fossil leaves hitherto found in higher southern latitudes are those of beeches, closely allied to existing southern species, brought by Darwin from Fuegia. In one locality alone beyond the forest region of the south have fossil plants been found; there were silicified trunks of trees in lava beds of Kerguelen's Island (discovered by myself forty years ago). It is deeply to be regretted that searches for shales containing fossils were not made either by the 'Challenger' expedition or by the various 'transit of Venus' expeditions that have recently visited this interesting island.

[3] *Flora Antarctica*, pp. 230, 240. See also Moseley in Journ. Linn. Soc. Botany vol. xv. p. 485, and *Observations on the Botany of Kerguelen's Island*, by myself, in the *Philosophical Transactions*, v. 168, p. 15.

it ever existed, having been the birthplace of that flora; and there are two reasons for adopting the opposite theory, that the southern flora came from the north temperate zone. Of these, one is the number of northern genera and species (which, from their all inhabiting north-east Europe, I have denominated Scandinavian),[1] that are found in all Antarctic and south temperate regions, the majority of them in Fuegia, the flora of which country is, by means of the Andes, in the most direct communication with the northern one. The other is the fact I have stated above, that the several south temperate floras are more intimately related to those of the countries north of them than they are to one another.

And this brings me to the latest propounded theoretical application of the laws of geographical distribution. It is that recently advanced by Mr. Thiselton Dyer, in a lecture 'On Plant distribution as a field of Geographical Research';[2] wherein he argues that the floras of all the countries of the globe may be traced back at some time of their history to the northern hemisphere, and that they may be regarded in point of affinity and specialisation as the natural results of the conditions to which they must have been subjected during recent geological times, on continents and islands with the configuration of those of our globe. This hypothesis derives its principal support from the fact that many of the most peculiar endemic plants of the south have representatives in the north, some of them living and all of them in a fossil state, whilst the northern endemic forms have not hitherto been found fossil in the southern regions. So that, given time, evolution, continental continuity, changes of climate and elevations of the land, and all the southern types may be traced back to one region of the globe, and that one palæontology teaches us is the northern.

A very similar view has been held and published at the same time by Count Saporta,[3] a most eminent palæontologist, in a suggestive essay entitled 'L'Ancienne Végétation Polaire.' Starting from Buffon's thesis, that the cooling of the globe having been a gradual process, and the Polar regions having cooled first, these must have first become fit for organic life, Count Saporta proceeds to assume that the termination of the azoic period coincided with a cooling of the waters to the point at which coagulation of albumen does not take place, when organic life appeared in the water itself. I have discussed Count Saporta's speculations elsewhere;[4] it is sufficient here to indicate the more important ones as bearing upon distribution. These are that the Polar area was the centre of origination of all the successive phases of vegetation that have appeared on the globe, all being developed in the north; and that the development of flowering plants was enormously augmented by the introduction during the latter part of the secondary period of flower-feeding insects, which brought about cross-fertilisation.

It remains to allude briefly to the most important general works on distribution that have appeared since the foundation of this Association. Of these, the two which take the first rank are Professor Alphonse de Candolle's 'Géographie Botanique,' and Mr. Wallace's 'Geographical Distribution of Animals.' Professor de Candolle's work[5] appeared at a critical period, when the doctrine of evolution with natural selection had only just been announced, and before the great influence of geological and climatal changes on the dispersion of living species had been fully appreciated; nevertheless it is a great and truly philosophical work, replete with important facts, discussed with full knowledge, judgment, and scrupu-

[1] See *Outlines of the Distribution of Arctic Plants*, *Transactions of the Linnean Society*, xxiii. p. 257. Read June, 1860.

[2] *Proceedings of the Royal Geographical Society*, xxii. p. 415 (1878).

[3] *Comptes rendus* of the International Congress of Geographical Science, which met in Paris in 1875, but apparently not published till 1877.

[4] Address of the President delivered at the anniversary meeting of the Royal Society of London, November 30, 1878.

[5] Professor Alph. De Candolle divides his subject into botanical geography and geographical botany; the distinction is obvious and sound, but the two expressions have been so long used and regarded as synonymous, and as embracing both branches, that they cannot now be limited each to one. Perhaps the terms topographical botany and geographical botany would prove more acceptable designations.

lous caution. Of its numerous valuable and novel features, two claim particular notice, namely, the chapters on the history of cultivated and introduced plants; and the further development of Humboldt's 'Arithmeticæ Botanices,' by taking into account the sums of temperatures as well as the maxima, minima, and means, in determining the amount of heat required to satisfy all the conditions of a plant's life, at the various periods of its existence, and especially the maturation of its seeds.

Of Mr. Wallace's great work 'The Geographical Distribution of Animals,' I cannot speak with sufficient knowledge of the subject, and can only appreciate and echo the high praises accorded to it by zoologists, for its scientific treatment of a vast subject.

The 'Géographie Botanique' was followed by the late Dr. Grisebach's 'Die Vegetation der Erde,'[1] which contains an admirable summary of the vegetation of the different regions of the globe as limited by their physical features, divested of all theoretical considerations.

For the largest treatment in outline of the whole subject of distribution, I must refer to the chapters of Darwin's 'Origin of Species,' which are devoted to it.

In reference to these and other works, very able and instructive discussions of the principles of geographical distribution are to be found in the presidential addresses delivered before the Linnean Society, in 1869, 1870, and 1872, by the veteran botanist, G. Bentham.

With Mr. Wallace's 'Island Life' I must conclude this notice, and very fittingly, for besides presenting an admirable account of the origin and migrations of animals and vegetables in oceanic and continental islands, it contains a complete and comprehensive analysis of those past and present conditions of the globe, astronomical, geological, geographical, and biological, which have been the earlier and later directors and controllers of the ever-warring forces of organic nature. In this work Mr. Wallace independently advocates the view of the northern origin of both the faunas and floras of the world.

I conclude with the hope that I have made the subject of the distribution of organic life on the globe interesting to you as geographers, by showing on the one hand how much it owes its advance to the observations made and materials collected by geographical explorers, and on the other how greatly the student of distribution has, by the use he has made of these observations and materials, advanced the science of physical geography.

The following Papers were read:—

1. *The Equipment of Exploring Expeditions Now and Fifty Years Ago. By* FRANCIS GALTON, *F.R.S.*

The equipment of a modern exploring expedition differs in many respects now from what it was in or about the year 1830, with the general result of increased efficiency and rapidity of execution. The standard instruments—namely, the theodolite, the sextant, the chronometer, and the azimuth compass—have not received any great improvements in the interval, and the best of those made in 1830 would be valued now. But they are made more handy and portable than they were, and at much lower cost for equal degrees of excellence. The modern water-tight cover, with the keyless winding arrangement of travellers' watches, is a great boon to them. The mercurial horizon, without which the sextant on land is almost useless for astronomical purposes, has been transformed from a lumbering trough shielded from the wind by a heavy glazed screen, which was difficult to fill and did not admit of the observation of low angles, into a very compact contrivance by Captain George, which is filled by tilting, and is sheltered from the

[1] Published in 1872. Translated into French under the title of *La Végétation du Globe*, by P. de Tchihachef, Paris, 1875.

wind by a piece of glass floating on the mercury. The liability to errors introduced by this arrangement is much smaller than might have been expected, and travellers speak highly of its merits. The appliances for measuring elevation above the sea-level have been greatly improved. The old method was to carry a mountain barometer, which, from the weight of the mercury and the fragility of the glass that contained it, was rarely carried far without breakage. Since then the aneroid has been invented, and the appliances connected with the boiling-point thermometer have been greatly improved. A traveller provided with these very portable instruments can use the aneroid for everyday purposes, checking its change of index error from time to time by boiling-point observations. Even the mercurial barometer has been rendered a comparatively portable instrument. The tubes are packed empty, and they are filled when required by Captain George's method, which in moderately careful hands is found to give good results. The enclosed thermometer for deep-sea observations is a recently invented instrument absolutely essential to accuracy.

The art of exploring ocean-depths and performing what has been called Thallassography, has been immensely improved, owing to the requirements of submarine telegraphy and of such scientific expeditions as that of the *Challenger*. Sir W. Thomson's method of sounding at the depth of many fathoms without checking the ship's course is in full use, but Dr. Siemens' bathometer has not yet been made practically serviceable.

The accuracy of thermometric graduation has been greatly increased by the verifications afforded by the Kew Observatory, which is the child of the British Association, established, and for a long time maintained, by a yearly grant from its funds, but now supported by the endowment of Mr. Gassiot. The errors in thermometers occasionally furnished even by the best makers in 1830, were such as would not be tolerated now. The verifications of Kew are extended to other instruments, and the influence of the Observatory for good is firmly established and appears to be yearly increasing. Of the other appliances for geographical travellers —such as scales for plotting, metal pens which were invented since 1830, and that admirable recent contrivance the stylographic pen—it is unnecessary to speak in detail. The binocular opera-glass is, practically speaking, a new instrument, and its merits as a night-glass were first found out long after 1830. The lunar tables of the 'Nautical Almanack' have been greatly improved of late years, for in 1830 their predictions of the place of the moon could not have been trusted as they now are for delicate determinations of longitude. Lastly, the means of instruction in the use of geographical instruments is at length afforded by the Geographical Society, who have erected a small observatory on the roof of their premises, where instruction is given on moderate terms to intending travellers.

The modern equipment of travellers as regards dress has been greatly improved by the general use of flannel, which is a most important preservative of health, but was neglected half a century ago. Thus, at much more recent times than 1830, the hardy Swiss guides had a horror of what they called a *coup-d'air*, or a chill on the mountain-top, when they were hot and perspiring; and no wonder, as they then all wore linen shirts next the skin. The modern loose form of dress, the shooting boots and easy overcoat, are a vast improvement on the pinched costumes of 1830. The derivation of the word paletôt conveys a history. The first warm and convenient coats used in England were reproductions long subsequent to 1830 of those used by sailors in rough weather under the name of 'pilot coats' (and were sometimes, for the sake of shortness, called 'p. coats' or 'pea-coats'). They quickly became the fashion, were copied and made more elegantly by the French, who adapted our name of 'pilot coat' to their own pronunciation of paletôt, and so we received it back from them. India-rubber and gutta-percha adaptations to articles of dress and manufactures generally date from a little subsequent to 1830; they are invaluable for many purposes to exploring expeditions. The form of tent has been greatly improved. Portable mackintosh and other boats are comparatively recent contrivances, and have done good service. Lucifer-matches had been invented, but only very recently, in 1830.

The equipment of a travelling party as regards packsaddles has been improved, chiefly through Australian experiences, where, moreover, the camel has been introduced as a beast of burden, with more success than the tamed elephant in Africa. The art of sledge-travelling has been vastly improved by the skilful cutting down of all superfluous weight, enabling travellers to drag more food, and so to be absent from their depôts for a larger number of days.

As regards food, the tinned meats, compressed vegetables, and condensed milk, which are invaluable during the first days of travel before the expedition has settled into regular ways, are all late inventions, and the merits of lime-juice are now far better understood than they were fifty years ago.

The *personnel* of a travelling party is decidedly improved. Whatever may be the state of the physique of the lower orders of the population, there can be no doubt that the upper orders are physically better developed than they were. They are, as I have good reason to believe, in the absence of direct measurements, taller; they achieve greater feats in running, leaping, walking, and other athletic performances than their grandfathers did. They lead healthier lives from the discontinuance of the heavy eating and hard drinking of old days, from the better aired sleeping rooms, the existence of proper means of washing, and the seaside or Continental summer vacation.

The greatest benefit of all to travellers is the modern rapidity and ease with which distant parts of the world are now reached. In 1830 it required 70 days sailing from England to reach the Cape of Good Hope, 120 days (in the S.W. monsoon) to reach Bombay, and 130 days to Sydney. It was 40 days' sail to New York, 42 to Jamaica, 56 to Rio, and 110 to Valparaiso. The length of time that the post now takes from London to these places is as follows: Cape Town 21 days, Bombay 18 days, Sydney 43 days, New York 10 days, Jamaica 18 days, Rio 21 days, Valparaiso 39 days; the average increase of speed being more than threefold. There is scarcely any important part of the world that cannot now be reached in two months from London; even the Antipodes are only six weeks' journey. This facility of communication is accompanied by a corresponding spread of commerce, and travellers can now easily refit themselves at distant points. It has recently occurred to the Geographical Society to have had to meet bills drawn upon her Majesty's consul at Zanzibar by a traveller in their employ, for which he had been furnished with goods by Arab traders at Nyangwé on the Upper Congo, as well as at places in Central Africa which had never before been visited by a white man.

---

2. *Isochronic Postal Charts. By* Francis Galton, *F.R.S.*

By 'isochronic' postal charts I mean charts that show the distances attained in all directions from the same starting point, by the post, 'in equal times.' Let us view in imagination the stream of travellers who leave London simultaneously and go as quickly as they can to their destinations, starting by the postal routes. Some of the travellers will be seen to leave the main lines at each successive halting-place, and to branch to the right and to the left, perhaps repeatedly and by various conveyances, before their journey is over. They may reach the same goal by different routes, though not at the same moment. In the meantime the travellers on the main tracks are swiftly moving ahead. At length every part of the world is reached. The course of the stream of travellers may be likened to the spreading of the tide as it advances over broad sands. The rising waters run quickly along certain channels. These diverge, subdivide, interlace, and join. After a little more time only a few isolated patches of dry shore can be seen, at last the whole surface is overspread by the water. In the maps I exhibit, I have endeavoured to represent this appearance upon all the postal routes from London. In accordance with the definition of 'isochronic' given above, I am obliged to suppose that the mails have been despatched simultaneously to all parts, and I show by bands of different colours where the travellers would be at different periods. All places within ten days' journey of London are coloured green, those between ten and twenty are orange, between twenty and thirty they are red, between thirty and forty they are blue, and those beyond forty are brown.

Isochronic maps would probably be of much convenience to tourists. They could be constructed for the Continent or for home excursions.

---

3. *On the Geographical Work of the Palestine Exploration Fund.* *By* TRELAWNEY SAUNDERS.

The author gave an account of the survey of Western Palestine, to which the Association had contributed, conducted by Lieutenant Conder and Lieutenant Kitchener, and now completed. It embraced nearly the extent attributed to the Land of Canaan, in the earliest specification of a geographical boundary to be found in Biblical history, viz., in the 10th chapter of Genesis. After an elaborate sketch of the work of earlier explorers, he proceeded to describe the survey of Lieutenants Conder and Kitchener. This had occupied from 1872 to 1877, and was executed on the scale of one inch to a mile, and he believed that when the great difficulties which the task had involved were considered—difficulties of climate, race, and fanaticism—the map would be found to possess a fulness and accuracy far beyond that of any other previously executed. It was now possible to undertake a systematic analysis of the natural features of the ground, its watercourses and drainage-basins, its plains and highlands, with a degree of precision and detail that was previously unattainable for lack of knowledge.

FRIDAY, SEPTEMBER 2.

The following Papers were read:—

1. *On the Progress of Geography in Asia during the last fifty years.* *By* Sir RICHARD TEMPLE, Bart., *G.C.S.I., F.R.G.S.*

The author described the physical geography of Asia, and pointed out the portions which, during the last half-century, had been surveyed, partially surveyed, or only explored. As regards India and Ceylon great progress had been made. From the base of the Himalayan range to the southernmost cape nearest Ceylon, the British territories have been mapped, for the most part, with as much minuteness as the best managed estates in Europe. The great rivers are well known; the altitude of many of the highest mountain-peaks has been determined. The country has been covered with a network of triangles, a large arc of the meridian determined, the geodesic contour of the land ascertained. In two provinces only, Bengal and Behar, is the field-survey wanting. The geography of Afghanistan and Beluchistan is, however, utterly incomplete. The territory here is not only difficult from its mountainous character, cold climate in many quarters, and desert character in others, but also rendered inaccessible to surveying parties by the fierce character of its inhabitants. During the recent war, however, a surveying staff was attached to the military establishment, by whom the route was surveyed and valuable results obtained. Still the work in Afghanistan is very incomplete. The geography of Beluchistan is even less advanced. Of the north-eastern portion considerable knowledge has been gained of late years. The Chinese have bestowed much labour on topography, but their surveys have not been scientific, their maps not precise, and the general geography is not exactly determined. The grave changes which have been brought about in Japan have led to a greatly increased knowledge of those islands. The Russian Government has done much in the northern parts of Asia. The physical geography of Persia is, as yet, very imperfectly known. The author passed on to notice the nautical and geological surveys, concluding by pointing out the principal problems that yet await solution.

---

2. *On the Hot-lake District and the Glacier Scenery and Fjords of New Zealand.* *By* Wm. Lant Carpenter, *B.A.*, *B.Sc.*, *F.C.S.*

The author had visited New Zealand in December 1880, and through the kindness of prominent men there had been able to see and learn a great deal, and had brought home a series of excellent photographs of places but rarely visited. These were exhibited. The lines of volcanic action in the North Island were first explained, and the general characteristics of the centre of the island were pointed out. The surface was composed either of acid volcanic or post-tertiary sedimentary rocks. The water-supply of the Hot-lake District was Lake Taupo, with an area of 248 square miles, 1,250 feet above the sea, with a depth considerably greater than that, through which ran the river Waikato, and from which subterranean channels led. Around its shores were many hot springs—geysers 100 feet high—mud volcanoes, fumaroles, &c. In the river valley 76 hot springs were visible from one station. The Hot-lake District proper was 40 miles N.N.E. of Taupo, about 240 square miles in extent, containing 16 lakes. Two were described—Rotorua, the largest, and Rotomahana, celebrated for its marvellous and unique terraces of nearly pure silica, deposited from intermittent hot springs that burst out about 100 feet above the lake, the basin of one of which was larger than that of the Great Geyser in Iceland. These were described in some detail, and the composition of the springs, as well as of the deposit (analysed by the writer), was remarked upon. A remarkable ravine, whose bottom was hot mud, with blocks of siliceous sinter floating therein, was noticed, and also the 'steaming ranges,'—and this part concluded with a short description of White Island, where was a lake whose water contained more than 10,000 grains of hydrochloric acid in a gallon (!) with large deposits of sulphur and sulphate of lime in the neighbourhood.

The Southern Alps were then generally described, running the whole length of the South Island, the highest peaks of which ranged from 10,000 to nearly 14,000 feet, with a snow line at about 8,000 feet. The enormous snow-fields and huge glaciers lying between 43° and 44° S. and 170° and 171° E. were noticed, as well as the evidences of past glacial action on a much grander scale, given by the glacier-formed lakes and fjords on the SW. coast, as well as by the huge moraines. The backbone of the whole was granitic, but on the side-slopes lay the older palæozoic rocks. Some of the existing glaciers were upwards of 18 miles long. In lat. 43° 35′ S., corresponding to that of Marseilles or Leghorn, a glacier descended to within 705 feet of the sea. The characteristics of the river-system that flowed from these were described, and instances given of their liability to sudden flood, and to rapid and great changes of bed, rendering it impossible to bridge them. The paper concluded with a notice of the rarely visited 'Sound' scenery of the S.W. coast, which in general appearance resembled that of Norse fjords, but the Sounds were not so long, although the cliff and mountain scenery was in many instances finer, sheer precipices of 2,000 to 3,000 feet, or upwards, rising from the sea, with mountains of 8,000 to 9,000 feet. The whole of this district was granitic, and the water at the head of the Sounds was deeper than at their entrances, indicating glacial excavation.

---

3. *On Oceanic or Maritime Discovery, Exploration, and Research.* *By* Captain Sir F. J. Evans, *R.N.*, *K.C.B.*, *F.R.S.*

---

4. *On the River Gambia.* *By* R. E. Cole.

SATURDAY, SEPTEMBER 3.

The Section did not meet.

MONDAY, SEPTEMBER 5.

The following Papers were read:—

1. *On the Progress of Arctic Research since the Foundation of the British Association. By* CLEMENTS R. MARKHAM, *C.B., F.R.S.*

The author, having pointed out that Martin Frobisher, Marmaduke, James Cook, Scoresby, and other noted Arctic explorers were Yorkshiremen, passed on to say that in 1831 the Asiatic coasts within the frigid zone had already been delineated by the Russians. But on the American side only portions had been traced by Franklin, Back, Richardson, and Beechey. Much difficult work had to be done before the complete outline of Arctic America could be laid down. The western and northern shores of Spitzbergen had long been known, Ross had rediscovered Baffin's Bay and so vindicated the fame of that gallant old navigator, and Parry had pressed westward for 300 miles to Melville Island, on a meridian far to the north of the American continent. Lastly, the Rosses were engaged in the discovery of Boothia and King William Island. Not only was the whole vast region to the north of 82° entirely unknown, but also extensive tracts to the southward of that parallel, especially between Parry's westward track and the American coast. The period covered by the labours of the British Association, and of its contemporary the Royal Geographical Society, has been a period of great though fitful activity in the work of filling up these blanks and of increasing our Arctic knowledge. In the present century, the north-west and north-east passages have been sought in order that scientific knowledge might be extended, that the relations between land and sea over a vast area might be understood, together with the numerous other interesting facts connected with a previously unknown region. Increase of knowledge is the great object of Arctic discovery; an object than which none can be more useful, none more praiseworthy; and when once the attempt to secure it has been commenced, our efforts ought never to be relaxed until the great end in view is fully attained. After tracing Arctic discovery from 1830 to 1854 and dwelling particularly on the Franklin search expeditions, Mr. Markham said the latter performed an enormous amount of valuable scientific work, adding materially to the sum of human knowledge, in addition to the performance of the humane mission on which they were primarily employed. The ample experience which was then acquired established the true methods for future polar search, which are now formulated into three Arctic Canons. The first is that, for satisfactory and complete results, an expedition must pass at least one winter in the ice in order to obtain a complete series of observations. The second is that full results as regards geology, zoology, botany, and geography can only be secured by the despatch of extended sledge-travelling parties. The third is that to reach an advanced position within the unknown area, it is necessary to follow a coast-line, trending northwards, with a westerly aspect. These three canons are equally important, but the last rule is that which has the most interest to the geographical inquirer. The experience of three centuries has taught us that inevitable failure and probable disaster are the consequences of pushing into the ice-floes away from land, while a successful advance is secured by keeping to a coast-line. Further, it is held that the best prospect of success is afforded by advancing along a coast trending northwards, with a westerly aspect. Such coast-lines usually have channels of open water along them, during some part of the navigable season. This fact in physical geography is ably discussed by Sir Edwary Parry in his remarks at the conclusion of the narrative of his third voyage. He had observed that the eastern coast of any land trending north and south was more encumbered with ice than shores having an opposite aspect. The east coasts of Greenland, Spitzbergen, and Novaya Zemlya are more or less blocked with ice throughout the summer, while navigation along the western coasts may annually be performed without difficulty. The west side of Fox's Channel, along Melville Peninsula, is loaded with ice, but there is little or no ice on the east side. In Prince Regent's Inlet ice always clings to the western shore of the channel, while the opposite shore is comparatively free from it. In Behring Strait the same fact has been observed. On the American side the water is comparatively warmer, and is navigable every summer to Point Barrow, while the Asiatic side is usually blocked with ice. A general motion of the sea towards the west causes the ice to set in that direction, when not impelled by contrary winds or local currents; and Sir Edward Parry suggested that this constant westerly motion was connected with the motion of the earth on its axis. Mr. Markham went on to review the expeditions made, and the work achieved between 1858 and 1876, and proceeded: We find that in every particular the results of the Arctic Expedition of 1875–76 justified the anticipations based upon former knowledge and experience. The examination of that portion of the previously unknown area which could be reached by the Smith Sound route was satisfactory, and completed the work in that direction. Consequently those reasons for continuing polar discovery which led to the despatch of the last expedition are now as strong as they ever were. Since the return of Sir George Nares in 1876, the greatest northern achievement has been the voyage of Professor Nordenskjöld along the north-east passage. The great Swedish explorer had prepared for this enterprise by the most exhaustive study of the subject in all its bearings, and by two voyages of reconnaissance, so that he may almost be said to have commanded success. The results of the voyage of the *Vega* are most valuable, as confirming and piecing together all previous work, and establishing the broad facts bearing on the hydrography of the Siberian Arctic Sea. Passing all this briefly in review, we have before us the results of Arctic enterprise during the period which embraces the labours of the British Association. In 1831 there were only unconnected and isolated discoveries in various directions. Now there is some approach to generalisation, to a comprehension of the geography of the Arctic regions, so far as discovery has extended, as a whole. This is the great result. We must study the means of reaching another coast-line trending northwards into the unknown region, with a western aspect. Looking round the circle which divides the unknown from the known, we find another such land in the Franz-Josef Land discovered by Payer and Weyprecht. There was an apparent difficulty in reaching this land because its most southern shore is in 80° N., almost as far north as the most northern part of Spitzbergen, and an ice-laden sea intervenes between the open water and the first base of operations. But this ice-laden sea is known to be navigable in August and September. This was proved by Payer in 1871, by the Dutch Expedition in 1878, by Captain Markham in 1879, and by Mr. Leigh Smith in 1880, when he reached Franz-Josef Land in a steamer, made important discoveries along it in August, and ascertained that the furthest western land he saw trended north and west. Mr. Leigh Smith has again sailed this year in the same steamer, still further to demonstrate that a base of operations on Franz-Josef Land may generally be reached, in an ordinary season. From this base a steamer may advance northwards along the west coast, and all experience leads to the belief that so long as that coast trends in a northerly direction, a steamer may, in most seasons, succeed in making her way along it. A vast field of discovery will thus be opened, promising all the valuable results that have ever been anticipated from polar research. By this route we have the prospect of the attainment of a very high northern latitude for winter quarters, the exploration of an unknown and peculiarly interesting region by means of sledges, and security for a safe retreat.

2. *On the Commercial Importance of Hudson's Bay, with Remarks on recent Surveys and Investigations. By* Robert Bell, *M.D.*

Few people have any adequate conception of the extent of this great American sea. Including its southern prolongation, James' Bay, it measures about 1,000 miles in length, and is more than 600 miles in width at its northern part. Its total area is about 500,000 square miles, or upwards of half that of the Mediterranean Sea in the 'old world' hemisphere. It is enclosed by the land on all sides except the north-east, where it communicates by several channels with the outer ocean. The principal or best known of these is Hudson's Strait, which is about 500 miles in length, and has an average width of about 100 miles. The resources of Hudson's Bay and the country immediately around it are varied and numerous, although as yet few of them are at all developed. The fur trade is the principal and best known business which has hitherto been carried on in these regions; but a large amount of oil, derived from the larger whales, the porpoises, walruses, white bears, and the various species of seals which frequent the northern parts of the bay, has been carried to New England, and small quantities, principally of porpoise and seal oil, have from time to time been brought to London by the Hudson's Bay Company. The other exports from the bay have been as yet but trifling. The fisheries, properly speaking, of Hudson's Bay have not yet been investigated. Both the Indians and Eskimos find a variety of fish for their own use, and fine salmon abound in the rivers of Hudson's Strait. Water-fowl are very numerous on both sides of the bay, and larger game on the 'barren grounds' in the northern parts, so that the natives, with prudence, may always have a plentiful supply of food. But perhaps the most important of the undeveloped resources of the country around the bay are its soil, timber, and minerals. To the south and west of James' Bay, in the latitude of Devonshire and Cornwall, there is a large tract, in which much of the land is good, and the climate sufficiently favourable for the successful prosecution of stock and dairy farming. A strip of country along the east side of James' Bay may also prove available for these purposes. To the south-west of the wide part of the bay the country is well-wooded, and although little or no rock comes to the surface over an immense area, still neither the soil nor the climate are suitable for carrying on agriculture as a principal occupation until we have passed over more than half the distance to Lake Winnipeg. This region, however, offers no engineering difficulties to the construction of a railway from the sea-coast to the better country beyond, and this, at present, is the most important point in reference to it. Some of the timber found in the country which sends its waters into James' Bay, may prove to be of value for export. Among the kinds which it produces may be mentioned white, red, and pitch pine, black and white spruce, balsam, larch, white cedar, and white birch. The numerous rivers converging towards the head of James' Bay offer facilities for 'driving' timber to points at which it may be shipped by sea-going vessels. Minerals may, however, become in the future the greatest of the resources of Hudson's Bay. Little direct search has as yet been made for the valuable minerals of these regions. I have, however, found a large deposit of rich ironstone on the Mattigami River, inexhaustible supplies of good manganiferous iron ore on the islands near the east main coast, and promising quantities of galena around Richmond Gulf and also near Little Whale River, where a small amount had previously been known to exist. I have likewise noted traces of gold, silver, molybdenum, and copper. Lignite is met with on the Missinaibi, gypsum on the Moose, and petroleum-bearing limestone on the Abittibi River. Small quantities of anthracite, and various ornamental stones and rare minerals, have been met with in the course of my explorations. Soapstone is abundant not far from Mosquito Bay, on the east side, and iron pyrites between Churchill and Marble Island, on the west. Good building stones, clays, and limestones exist on both sides of the bay. A cargo of mica is said to have been taken from Chesterfield Inlet to New York, and valuable deposits of plumbago are reported to occur on the north side of Hudson's Strait.

The author concluded by discussing the facilities of access to this district, pointing out that the formation of ice in the harbours during the winter was the main obstacle to continuous commerce by sea.

3. *On the Island of Socotra. By* Professor BAYLEY BALFOUR, *M.D.* See Reports, p. 482.

---

4. *A Journey to the Imperial Mausolea east of Peking. By* F. S. A. BOURNE.

TUESDAY, SEPTEMBER 6.

The following Papers were read:—

1. *Comparative sketch of what was known in Africa in* 1830 *with what is known in* 1881. *By* Lieut.-Colonel J. A. GRANT, *C.B., F.R.S.*

The author said that in fifty years a great deal had been done towards opening out the centre of Africa as well as its surroundings. There were no lights or lighthouses around Africa prior to 1855, whereas now there were 129 harbour lights, all of which were maintained. The first light was erected at Cape Coast Castle. The sources of the Nile, the Niger, the Congo, the Zambesi, and the Limpopo had been discovered. A dozen lakes of great magnitude, and the whole physical aspect and resources of the continent, were now tolerably well known. The cutting of the Suez Canal, which was opened in 1869, had had a most beneficial effect upon the continent. The discovery of Lake Victoria Nyanza in 1863 was an event of great magnitude, and Captain Speke and the reader of the paper were enabled to put at rest the theories as to the source of the Nile, as they found that the parent of the Nile took its rise in the newly-discovered lakes. Speaking of the labours of Sir Samuel Baker and Mr. H. M. Stanley, Colonel Grant said that the benefits of those labours would be reaped in after years. The almost insurmountable labour they went through in putting steamers upon the Victoria Nyanza would be of untold advantage hereafter. Speaking of Cape Colony, the author said that the slave trade had been abolished in 1808, but slaves were sold until December, 1834, when all slaves were emancipated in British dominions. The colony since those days has made immense progress. The additions to knowledge of successive discoverers were described in detail.

---

2. *Some Results of Fifty Years' Exploration in Africa. By the* Rev. HORACE WALLER.

Geographical interest fifty years since chiefly centred upon the countries lying between the western fringe of the Sahara Desert and the Atlantic; indeed the Niger river absorbed most of the enthusiasm which had been aroused by Denham and Clapperton. It was in the year 1830, the year of the Society's birth, that Lander traced the Niger to the sea. The countries bordering upon the western coast of the Sahara Desert, which are watered by the Niger and its tributaries, have an interest peculiarly their own. The travels of Captain Vincent, of Barth, Overwig, Richardson, and others between 1849 and 1857, show that the comparatively advanced state of civilisation which prevails in these densely populated districts may be due to the very great difficulty of communicating with the French settlements on the west and the British possessions to the south-west. For ages the strict Moslems of these lands have preferred to draw those supplies which are needed amongst the Berber tribes in Timbuctoo, in Barin, Kuka, and other cities, from the marts of Algiers, Tunis, and Tripoli. There, at all events, Arab met Arab. The additions to our previous knowledge of the Fari country and the Gaboon river were mainly secured to us by the adventurous exploits of M. Paul de Chaillu in the years 1857, 1865, and 1867. From 1866 to the present date the

French have been busy on the Ogorvi. The Marquis de Compeigne in the year 1874 saw enough to make it probable that the great body of water which it carried to the sea was drained from no very distant area. They must, however, continue to look for the reports of the intelligent French officers under Count de Brazza before they could trace the course of the river for any great distance inland. Some particulars of the so-called Congo country had been acquired by Mr. Grandy, who traversed part of it when under the auspices of the Royal Geographical Society; but, at the sole cost of Dr. Young, he went in 1874 to seek for Dr. Livingstone, who it was imagined would probably come out that way. The news of Livingstone's death rendered further progress unnecessary. Painstaking work characterised the endeavours of Mr. Walker to explore the Okanda in 1866, and the same must be said of Lieutenant Serval previously, in 1862. Both France and Germany had vied with each other in projecting scientific discoveries in these regions under Compeigne, March, and Gussfeldt, but that success had not attended them which they could have desired. The great discovery of the diamond fields, in 1869, had a tendency to eclipse the work done by such travellers as Elton, Vincent, Erskine, Mohr, Moffatt, and Mackenzie, but nobody who had watched the question could fail to see what March had done, for instance in his searching for gold, or what the influence of John Mackenzie had been for good amongst the Bamangwato people. The results of Livingstone's travels were summarized. The discoveries of Speke, Sir Samuel Baker, Grant, Stanley, Cameron, and others, were also noticed. The work of Stanley, he said, was to clear up several gaps in the explorations of Burton, Speke, and Grant, and thenceforward to turn his attention to the waters of the Lualaba. He visited the Victoria Nyanza, and examined its western boundary, and spent some time at the capital of Uganda. Shortly after he discovered Lake Alexandra, and then fell back on Lake Tanganyka. Passing to the spot described by Cameron as the Lukuga, he proceeded in a north-westerly direction until he finally found himself embarked upon the greater venture—his descent of the Lualaba. He overcame obstacles of every kind, and made that remarkable voyage to the sea which they would always think on with amazement. Later work of great value has been done upon the lakes Nyanza and Tanganyka, and our last intelligence is extremely valuable and interesting.

---

3. *On a recent Visit to the Gold Mines of the West Coast of Africa. By* Commander CAMERON, *R.N.*

---

4. *An Account of a recent Visit to Dahomey. By the* Rev. J. MILUM.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION—The Right Hon. M. E. GRANT DUFF, M.A., F.R.S., F.L.S., F.R.G.S., Governor of Madras.

[For Mr. Grant Duff's Address, see page 752.]

THURSDAY, SEPTEMBER 1.

The following Papers and Report were read:—

1. *On Societies of Commercial Geography.* *By* EDWARD J. WATHERSTON.

The author traced the progress of the German societies of 'Commercial Geography' (Vereine für Handelsgeographie), established in Berlin towards the end of 1878, by Dr. Jaunasch, a well-known political economist and statistician. These societies already have agents in all parts of the world, a 'centralverein' in Berlin, and several periodicals supported by their members; one, 'The Export,' abounding in information to merchants and manufacturers; another, called 'Geographische Nachrichten für welthandel und Volkswirthschaft,' and a third, 'Handelsgeographisches Museum,' lately published. The objects of the societies are twofold—first, to give their members, nearly all merchants and manufacturers, the latest reliable information relating to the channels into which the export trade of the country should be directed; secondly, to establish agencies in all the principal commercial towns in the world.

This is done after the model of our famous Lloyd's. In like manner as Lloyd's agents report concerning ships, shipwrecks, and all matters relating to navigation, to the headquarters in London, so the German agents send in reports upon all matters relating to the commercial requirements of their districts to the 'Centralverein für Handelsgeographie' in Berlin, which reports are published in full in the 'Geographische Nachrichten,' sold to non-members for the sum of two marks, or 2*s*. The list of agents includes some of the most eminent Germans settled abroad, men of scientific renown, anxious for their country's welfare. Last year the societies held a 'Congress' at Berlin, and the speeches, reported at full length in a 'Bericht über die Verhandlungen des Ersten Congresses für Handelsgeographie,' show the progress which has been made in an attempt to secure for Germany commercial relations with the entire world.

Our own and other Governments, doubtless, are doing much to supply an admitted want—viz., a knowledge of foreign manufacturing and commercial capacities and requirements. The British Government, for example, publish every year a host of Blue-books, under various titles, giving a mass of most valuable information concerning our export and import markets, the demands of trade, and similar matters. There are among them the 'Reports of H.M. Secretaries of Embassy and Legation on the Manufactures, Commerce, &c., of the countries in which they reside;' somewhat similar are the 'Reports from H.M. Consuls on the Manufactures, Commerce, &c., of their Consular Districts,' more numerous even, and in some respects more valuable, as entering more into details. Then there are monthly and annual 'Accounts relating to the Trade and Navigation of the United Kingdom,' summed up and enlarged in a huge 'quarto,' known as the 'Annual Statement,' issued by the Board of Trade, and half a score of other Blue-books, described variously as 'Statistical Abstracts,' 'Agricultural Returns,' 'Special Reports,' and under other names.

But vast as is the information afforded, their very vastness makes them all but useless to the classes whom they are intended to serve. Time is wanted to digest the details, and, moreover, the Blue-books are made the more unavailing to practical men of business, in that not one of them has so much as an index to guide the reader through its mazes. Similar publications of foreign Governments are better edited, notably those of the United States, of Germany, and of Italy. The author strongly advocated the early establishment of similar institutions in tha United Kingdom—trade, as he believed, not requiring protection, but development.

To begin with, our own Blue-books—together with those of Germany, Italy, and France—should be made useful, by concentration and extracts, to our mercantile community, who at present scarcely know of their existence.

---

2. *Corn or Cattle: a Comparison of the Economic Results of Agriculture and Cattle-raising in relation to National Food-supply.*[1] *By* WILLIAM E. A. AXON, *M.R.S.L., F.S.S.*

The people of Great Britain are largely dependent for daily bread upon supplies from foreign sources, and the proportion of imported over home-grown foods is steadily increasing. So marked, indeed, has this tendency become in late years, that an American publicist has roundly asserted that 'if every acre of land in the British Isles were cultivated to its utmost capacity, the inhabitants could not raise food sufficient to supply the common necessaries of life.'

The amount of land in the United Kingdom devoted to permanent pasture is 24,717,092 acres, calculated to produce, at the rate of 50 lb. of flesh-meat per acre, 1,235,854,600 lb., which, at Mr. Greg's estimate of consumption of 3 lb. per day, shows a sustaining power for 1,128,634 persons per annum. The corn crops cover 10,672,086 acres, and the average yield of grain would be 17,929,104,480 lb., which at 2 lb. per head per day would feed 24,560,417 persons. Hence, without reckoning at all on the green crops, we have a sustaining power for 25⅔ millions of persons.

There have been various estimates as to the extent of English food-production. Mr. Caird supplied figures from which, in 1877, Mr. Stephen Bourne calculated the average corn-growth at 54,000,000 cwts.; but it is a gradually decreasing quantity. Mr. Bourne further reckons the growth of English flesh-meat at 25½ million cwts., a much higher estimate than would follow from the basis adopted by Mr. Greg.

But let us suppose the present process by which corn-growing districts have gradually been converted into grazing lands to continue until the entire available surface is devoted to cattle-raising. The total of arable and pasture acreage of the United Kingdom, in 1880, was 47,586,700, which, at a production of 50 lb. weight of butchers' meat per annum, would give a net result of 2,379,335,000 lb., or an amount sufficient, at 3 lb. per day, to feed 2,172,908 persons. If mankind were exclusively carnivorous, a much larger quantity would be required. The Canadian boatmen and the Esquimaux, when deprived of other food, consume from six to eight pounds daily. If, however, instead of being devoted to cattle-raising, we suppose the same acreage to be under corn crops, and to produce on an average 1,420 lb. to the acre, we have an annual return of 67,673,114,000 lb., or an amount sufficient, at two pounds per day, to feed 92,702,896 persons. After leaving an ample margin for any diversity of opinion as to the bases of such calculations, it is clear that there is sufficient material in our own land for the food of its people. The real remedy for over-population is food reform. Thus Dr. C. D. Hunter argues that 42 men could be supported on 100 acres devoted to sheep-raising, 53 on a dairy farm, 250 on wheat, and 683 on potatoes.

The British farmer, in face of the competition of cheap foreign-grown corn, has turned his attention more and more to cattle-raising, but there are not wanting

[1] Published in full as a pamphlet by John Heywood, Deansgate, Manchester, and 11, Paternoster Row, London.

signs that in the future he will encounter an equally keen rivalry in the production of flesh-meat. We have seen that, even with the present averages, the real food-value of cereals is enormously greater than that of the produce of the stock farm. It must further be remembered that whilst the productiveness of stock is strictly limited, that of the land devoted to corn and vegetables can be greatly increased by scientific farming. The late Mr. J. J. Mechi stated that from his farm (naturally much below the average quality of soil) he obtained a return of 13*l.* an acre, whilst the general one is but from 4*l.* to 5*l.*

In the matter of food, the poor and dear has been selected, to the neglect of the cheaper and better. The ignorant have taken *cost* as a measure of *value*, and, aping the luxurious habits of their wealthier neighbours, the poor are spending upon beef and bacon the money which would be much better employed in the purchase of the fruits of the earth. The diffusion of knowledge on the relative values of various kinds of food may be expected to correct some of the evils arising from the present popular errors as to the necessity of a flesh diet, or its superiority over one derived from fruits or cereals. The productiveness of the land might be improved by the removal of legislative hindrances to its free culture, and by returning to it the excreta of our teeming populations. The encouragement of fruit-growing is as legitimate an object of national concern as the development of fisheries.

---

3. *Report of the Committee on the manner in which Rudimentary Science should be taught, and how Examinations should be held therein, in Elementary Schools.*—See Reports, p. 148.

---

4. *Agricultural Statistics and Prospects. By* Wm. Botly, *M.R.A.S.*

The paper gave in a tabular form the acreage of the various crops in 1880; the number of cattle, sheep, pigs, and agricultural horses in the United Kingdom, with the increase or decrease under each head thereof, from which it appears that in the year 1880 there is a decrease in the

		Acres
Acreage of corn of		105,373
Green crops	decrease	125,263
Flax	increase	36,461
Hops	decrease	966
Bare, fallow, and uncropped arable	increase	90,514
Clover, and artificial grasses, under rotation	decrease	61,680
Permanent pasture, exclusive of heath and mountain land	increase	321,187
Orchards and gardens in two years	„	18,000
Woods and plantations since 1872 have	increased	222,000

Live Stock in 1880

Cattle	decrease	90,383
Pigs	„	314,618
Sheep	„	1998,338
Horses used in agriculture	„	25,714

Imports in 1880.

Cattle, sheep, and swine, an increase of		136,942
Wool	increase	49,230,785 lbs.
Cheese	decrease	15,665 cwts.
Butter	increase	274,196 „

Eggs	decrease	160,401 great hundreds.
Meat	increase	287,752 cwts.
Wheat, beans, barley, maize, oats, peas, and flour of all kinds . .	decrease	2,203,870 cwts.

Independently of eggs, poultry, game, live stock, &c., &c., we imported in 1880, meat, wheat and other cereals, butter and cheese, 139,166,859 cwts., *i.e.*, in weight, 15,586,688,208 lbs. avoirdupois.

The author does not despair for the future of agriculture, observing that we must attract more capital, skill, and enterprise to it, without regard to the politics of the tenant; he must have long or equitable leases, *i.e.*, security of tenure, with compensation for all unexhausted improvements, and full control over the game. Also there must be a sufficient number of decent cottages for the labourers on the farm, with so many rods of garden ground to each to grow vegetables for himself and family, thus training them to dig, weed, and hoe, keeping the man at home, and fitting his family for after-life, either at home or in emigration.

---

5. *A General Banking Law for the United Kingdom.* By Wm. Westgarth.

The condition of banking law in this country is most unsatisfactory, owing to the complete want of uniformity in banking constitution. It is not necessary by law for any of our very many banks to be constituted alike, and thus every bank is of necessity a separate and not seldom a rather intricate study for anyone having dealings with it. Again, the banking law is different respectively for England Scotland, and Ireland.

Considering how general banking now is, and that the public may be regarded as composed mainly of bankers and their customers, simplicity and uniformity of banking constitution have become a necessity. At present, for example, the professed capital and share of a bank may give us the following almost interminable variety. The capital may be paid-up capital, or it may be partly of that kind and partly of what is called Liability Capital; and this latter kind of so-called capital may be of two sorts, namely, a capital that may be called up by the bank, and a 'Reserve' capital that may not be called except in insolvency or liquidation; and these three different kinds of capital may be in any proportion one to another. Then again, the bank share, besides being constituted variously like the capital, of which it is a small section, may be further in endless variety of amount, no one bank in this respect, any more than in others, being bound to resemble another.

But banking is substantially one kind of business throughout the country, and therefore may admit of the great convenience of a more simple and uniform constitution. Towards this attainment, the term capital should have but one meaning, namely that of paid-up capital, which, if we except the ever-clashing theories of professed economists, and the confusing license of present banking law, is the meaning generally given to the word. Then as to the bank share, it might be uniformly of one and the same amount, and that some considerable amount, say 100*l.* The tendency of large shares is to give a responsible proprietary, and such is only due to the public from a bank. Lastly, as to liability, there ought to be something beyond paid-up capital, while on the other hand, public opinion has decided against unlimited liability. Above all, there ought to be uniformity of liability, both in kind and amount, so as to be easily intelligible to all.

Upon these lines, the proposed General Banking Law for the United Kingdom was to consist mainly of three clauses; first, the banking term Capital to mean, always and only, Paid-up Capital; second, the Bank Share to be uniformly of 100*l.*; third, Liability to be of the 'Reserve' kind only, and equal to amount of Capital.

All the banks of the United Kingdom might at once adjust themselves to such a law by mere nominal changes in capital and share. This would not, however, in the compulsory sense, be either fair or reasonable in many existing cases of banking diversities, and the law would therefore chiefly concern new banks. But there would probably soon be a disposition in the pre-existing banks to place themselves in conformity with a law so universal and intelligible.

FRIDAY, SEPTEMBER 2.

The PRESIDENT delivered the following Address:—

THE nature of the address with which it is my duty to commence the proceedings to-day, is commanded by circumstances. It must necessarily be historical, and take the shape of a rapid review of the fortunes of Section F since its came into existence.

This is, as we all know, the fiftieth anniversary of the British Association, but it is not the fiftieth anniversary of the Section to which we more especially belong. That Section was called into life at the Cambridge meeting in 1833, a year which will be long famous in English history in connection with a movement of a very different kind, a movement which was, indeed the expression of the distrust excited in many minds by our parents, Science and Liberalism.

We were at first entirely devoted to statistics, to the 'investigation,' to use the words of the official recommendation of the Section, 'of facts relating to communities of men which are capable of being expressed by numbers, and which promise, when sufficiently multiplied, to indicate general laws,' and Professor Sedgwick, the President of the Association for 1833, in the address with which he closed the proceedings, carefully limited the functions of the Section to the inquiries which furnish 'the raw material of political economy and political philosophy.'

Our first President was Mr. Babbage, who lived on into our own times, and whom some who are here present must have known well, whilst among the names of those who gathered round him as a committee were those of Empson, Hallam, Jones, Malthus, and Lubbock.

Hardly had our Section itself been created than it produced the Statistical Society, which, in the words of a speaker at the Edinburgh meeting in 1834, 'acknowledged itself the offspring of this institution,' and was indeed one of its first definite results.

At the Dublin meeting in 1836, our Section was again presided over by Mr. Babbage, who read a paper upon a subject which was destined to become, somewhat later, of great importance, on an experiment, namely, in the creation of co-operative shops for the supplying workmen with the necessaries of life, which, begun as far back as 1812, had come to an end in 1832.

On this occasion, too, appears, for the first time in our records, the honoured name of Mr. William Rathbone Greg, then a very young man, who became, in after years, so well known as a writer upon some of the questions with which we are occupied, and who contributed a paper on the 'Social Statistics of the Netherlands.'

We are reminded of the vast changes which have taken place in our times when we observe, that at the Bristol meeting in 1837, Dr. Lardner pointed out as if it was a great matter, that the introduction of railways between various points had actually increased the number of travellers between those points in the proportion of four to one.

At Liverpool in 1837, a committee was appointed for the advancement of Statistical Science, and the British Association volume for that year contains a report on the statistics of the Deccan by Colonel Sykes, which was creditable for its day; but the proceedings of our Section at Newcastle in 1838 were of little interest.

In 1839, when we met at Birmingham, we had the honour to have Mr. Hallam for our chairman; but no record of anything which that great historian said or read on the occasion seems to have been preserved, nor are the minutes of the Glasgow meeting in 1840 at all more interesting.

The meeting of our Section at Plymouth, in 1841, produced nothing that invites remark, but in the volume for 1842 there is a Report on the Vital Statistics of the large towns of Scotland, drawn up under the authority of some of the members of Section F, which had a certain importance.

Our Section was not very active at the Cork meeting in 1843, nor again when we met in this city in 1844.

The proceedings in 1845, 1846 and 1847 were somewhat more notable, but are very briefly reported, and the same may be said of all the years up to and inclusive of 1855. Observe that I am far from admitting that they were not useful in their day, as stimulating discussion and leading to valuable legislation. They have had the fate of the heroes who lived before Agamemnon. The persons who made the brief *resumés* of the papers read in those years, which are to be found in our annual volumes, but ill-supplied the place of the 'vates sacer.'

The last meeting at which our Section assembled under its old title and in its old conditions was that held at Glasgow in 1855, and our last president was Lord Houghton, then Mr. Monckton Milnes.

In 1856 at Cheltenham, a resolution was passed, I believe, on the initiative of that highly gifted, all-accomplished and ever-helpful man, which changed the name of Section F, and made it, what it has remained ever since, the Section of Economic Science and Statistics.

On that occasion too, our proceedings were for the first time opened by an address, though that address, having been prepared before the resolution just alluded to was passed, dealt exclusively with the subject of statistics. That it was ably dealt with, you will conclude, when I say that the author of the address was Lord Stanley, now Lord Derby, for even then, a quarter of a century ago, he had begun to display on all public occasions that wide knowledge and painstaking mastery of his subject, which have given him so great an influence amongst educated men of all parties in England, and which it is safe to prophesy will, when a sufficiently large selection of his addresses is rescued from the newspapers and published, give him in some respects a greater name with posterity than almost any statesman of our times. The main object of his address on this occasion was to urge the advantage of establishing a Statistical Department of Government, charged with the annual publication of such facts, relative to the management of internal reform, as are reducible to numerical expression.

In 1857 Archbishop Whately, who was by that time far advanced in years, and no longer the Whately of the Oriel Common-room, did not follow the example which Lord Stanley had set him, but opened our Section with a few remarks of a rather obvious kind.

Our venerable friend Sir Edward Baines, in 1858, was perhaps also too brief, but he took skilful advantage of the revelations of Mr. Sidney Herbert's commission on the health of our troops, then fresh in the memory of men, to enforce the utility of statistics and to show that arithmetic 'which some thought so heartless, was rising up as the most powerful advocate of the value of human life and health and of all that can purify and elevate society.' He followed up his address, too, by an important paper on the woollen manufactures of England in general and of Leeds, where the meeting took place that year, in particular.

1858 was, I may observe, rather exceptionally rich in good papers, which was hardly the case with 1859, when we were gathered together at Aberdeen under Colonel Sykes, then Member for that city.

The address of Mr. Senior at Oxford, in 1860, was a protest against the unscientific character of some of the papers read in our Section during the years that had elapsed since 1856. He explained that he used the word unscientific not dyslogistically but only distinctively, the tendency he blamed being that to stray across the bounds of science into the realm of art. 'A science,' he said, 'aims only at supplying materials for the memory and judgment. It does not pre-suppose any purpose beyond the acquisition of knowledge. An art is intended to influence the will: it pre-supposes some object to be attained, and it points out the easiest, the safest, or the most effectual conduct for that purpose.' He concluded by advising that we should keep as much as possible within the strict limits of statistics and of economic science as understood by the School to which he belonged.

In 1861 we met at Manchester, under the superintendence of Mr. Newmarch, who premising that there was some danger of undue importance being attached to what had been achieved in an age of physical discovery, vindicated the right of economic science and statistical inquiry to a high place amongst the agencies which have most contributed to the great advance which has lately been made by civilized mankind.

It was a year of important papers; one on the Progress of Manchester from 1840 to 1860, by Mr. David Chadwick; another by Mr. Molesworth on the Progress of Co-operation in Rochdale; and a third by Mr., now Sir Edward, Reed, on the Statistics of the Iron-cased Ships of the British Navy, being amongst the most interesting.

The address of Mr. Edwin Chadwick to this Section in 1862 is not, I think, printed in the annual volume, and Mr. Tite, who presided in 1863, made only a very few observations; but in both years some good papers were read, one by Mr. Herman Merivale upon Colonization and another by Mr. Dunning Macleod upon Political Economy, in 1862; and by Mr. Purdy, on the Decrease of the Agricultural Population of England, in 1863.

The address delivered at Bath by Dr. Farr, in 1864, was one of the best to which our Section has listened, and well worth recurring to. His object was to give a brief outline of the condition of statistical science at the time, and he succeeded admirably. It is indeed surprising how much matter of incontestable and permanent value he contrived to pack into twelve pages, and this although he sometimes diverged, perhaps, just a little into politics.

In 1865 the present Lord Derby again presided over us, treating *inter alia* the question how far our subjects ought to form part of the business of a strictly scientific Association, and coming to the conclusion that our functions are rather to suggest and stimulate than to originate thought. He further spoke at some length and with many illustrations, of the use of the statistical method.

In 1866 we met at Nottingham, under the guidance of Professor Thorold Rogers, who discussed several of the questions that were prominent at the time, such as the statistics of the live stock in England, a subject brought into prominence by the cattle plague; the state of the money market in that year of panic, and the fears that were expressed as to to the exhaustion of our coal-supply. I notice too, in his address, a phrase marked by his usual epigrammatic felicity and which should be remembered. 'The economist,' he said, 'is constantly labouring to refute men's hasty sympathies by an appeal to their deliberate reason.'

In 1867, at Dundee, I had myself the great honour of presiding over your deliberations, and we had a good many interesting papers relating to the statistics of the locality.

In 1868 our Section was presided over by Mr. Samuel Brown, of the Society of Actuaries, who devoted his address to a rapid survey of the various questions most likely to interest students of our science which had come before the public since the Dundee meeting, viz., to Technical Education, to the relations between Labour and Capital, to the purchase of the Electric Telegraphs by the State, to Weights and Measures, to Monetary Conferences, and to Insurance. Speaking of the latter subject, with which he was exceptionally qualified to deal, he observed: 'Vital statistics are now assuming a form which enables the most complicated problems of human life to be dealt with as if they were certain and simple events, yet little more than a century has elapsed since the Attorney- and Solicitor-General of that day, when reporting on the application for a Royal Charter to the first Society formed on scientific principles for the assurance of life, objected to it on the ground that its success must depend on calculations taken on tables of life and death, whereby the chance of mortality is attempted to be reduced to a certain standard. "This is a mere speculation," they observe, "never yet tried in practice, and consequently subject, like all other experiments, to various chances in the execution."'

The petition was dismissed, but the Society (the Equitable) was formed, and in spite of the gloomy prognostications at its birth had afterwards, at one time, nearly 20,000,000*l*. of assurances on lives in force together.

The proceedings at Exeter, in 1869, were opened by an address from Sir Stafford Northcote, in which, in addition to making some very curious comparisons between the statistics of Devonshire and Lancashire, he illustrated the working of the Law of Variation and the Law of Stability, pointed out the use of imagination in giving life to the details which statisticians accumulate, characterised the present as pre-eminently a statistical age, and spoke some words of warning, not unneeded, against an indulgence in our national weakness for waste.

At Liverpool, in 1870, we were presided over by Mr. Jevons, who amongst many important observations made the following, which should be had in remembrance if ever the relations of our Section to the other parts of the British Association are again brought under review:—

'I have always felt great gratification that the founders of this Association did not in any narrow spirit restrict its inquiries and discussions to the domain of physical science. The existence of this section is a standing recognition of the truth that the condition of the people is governed by definite laws, however complicated and difficult of discovery they may be. It is no valid reproach against us that we cannot measure and explain, and predict with the accuracy of a chemist or an astronomer. Difficult as may be the problems presented to the experimentalist in his investigation of material nature, they are easy compared with the problems of human nature, of which we must attempt the solution. I allow that our knowledge of the causes in action is seldom sure and accurate, so as to present the appearance of true science.

'There is no one who occupies a less enviable position than the political economist. Cultivating the frontier regions between certain knowledge and conjecture, his efforts and advice are scorned and rejected on all hands. If he arrives at a sure law of human nature, and points out the evils which arise from its neglect, he is fallen upon by the large classes of people who think their own common sense sufficient; he is charged with being too abstract in his speculations, with overlooking the windings of the human heart, and with undervaluing the affections.

'However humane his motives, he is lucky if he escape being set down on all sides as a heartless misanthrope. Such was actually the fate of one of the most humane and excellent of men, the late Mr. Malthus. On the other hand, it is only the enlightened and wide-minded scientific men who treat the political economist with any cordiality. I much fear that, as physical philosophers become more and more successful, they tend to become, like other conquerors, arrogant and selfish; they forget the absurd theories, the incredible errors, the long enduring debates, out of which their own knowledge has emerged, and look with scorn upon our economic science, because we are still struggling to overcome difficulties far greater than ever they encountered. But again, I regard the existence of this Section as a satisfactory recognition of the absolute necessity of doing our best to cultivate economic subjects in a scientific spirit.'

This address may be said to mark an epoch, because in the course of it the Chairman was able, for the first time in English History, to use words which many active members of our Section who did not live to hear them would have rejoiced to hear:—'I am glad to say that in spite of all opponents we have an Education Act;' and he went on to advocate a great and unaccomplished reform, the applying to useful objects of the funds of our innumerable and most pernicious dole charities.

In 1871, at Edinburgh, we met under the genial rule of Lord Neaves, and it is curious to observe how the uncontrollable mirthfulness of that eminent judge kept breaking through the gravity of his address, and illustrating the old words:—

'All things are big with jest, there's nought so plain
But may be witty if thou hast the vein.'

It is likewise noticeable that although, as we have seen, we were statisticians first and economists only twenty-three years afterwards, Lord Neaves treats our Section as mainly economic, and considers statistics as a mere accessary. This view, however, was not taken by the members of the Section, who contributed that year some very important statistical papers, amongst them one of peculiar interest in the locality where it was read, on the scheme of the Merchant Company with reference to the great Educational Hospitals of Edinburgh.

At Bradford, in 1873, Mr. Forster did not deliver an address, but made a speech characterised by his usual vigour, hopefulness, and knowledge of affairs.

At Belfast, in 1874, the members of this Section had the good fortune to do incidentally a great practical and immediate service, by bringing to an end a strike which had caused great inconvenience, and they received the thanks of the local authorities. The address to the Section was delivered by Lord O'Hagan, and an interesting paper, read by Sir George Campbell, bore the (at first sight) rather startling title 'On the Privileges over Land wrongly called Property.'

Our Belfast volume, that of 1874, contains the report of a Committee presided over by Lord Houghton, which was appointed to inquire into the economic effects of combinations of labourers and capitalists. That Committee called a conference, which assembled at 22, Albemarle Street, where a deputation from the National Federation of Associated Employers of Labour met a number of persons representing labour, and discussed a variety of questions of common interest.

'The discussion at the conference,' says the report, 'was carried on in the most friendly spirit, and, in the opinion of your Committee, with manifest utility towards the elucidation of the questions at issue. From the employers your Committee have, moreover, received valuable written answers to their inquiries; whilst the "Beehive," the principal organ of the employed, said of the conference, "The case was stated with great frankness, and the attack and defence was carried on in perfect good humour for three hours; and whether any conviction on either side was altered or not, it was proved very distinctly that such meetings, if held more frequently, could not fail to beget a clearer view of the questions in dispute on both sides, and a stronger disposition than now exists to arrange differences in a friendly and peaceable spirit."'

The address at Bristol in 1875, was delivered by Mr. Heywood, and contained much information as well about the trade as the educational facilities of the neighbourhood, while various papers of merit were read, including one upon national education by Mrs. Grey; one on the coal question by Mr. Jevons, and one on the value of European life in India by Dr. Mouatt.

At Glasgow, in 1876, Sir George Campbell presided, and brought his great knowledge of India to bear upon various important problems.

Amongst other things he made the following observations upon the use of narcotics and stimulants:—

'I have been led into the suggestion that these things are very much a matter of race by observation of the very singular way in which in Asia the population are divided into those who use opium and those who use alcohol, according to race lines, even in countries where the facilities of obtaining the one or the other are precisely similar. In the east of India I found that the consumption of opium in the various districts was just in proportion as a Turanian or Chinese element prevailed in the population. The Aryan races of India never take to opium in a very great degree, except in the case of the Sikhs, whose religion prohibits the use of tobacco. Even in the districts where the poppy is almost universally cultivated by the ryots (and they supply the opium which the Chinese consume), it is a happy fact that the native population does not take to the common use of opium; and there are no greater symptoms of the ill effects of the drug than in districts where it is very rare and dear—far less so than in districts where the cultivation is not permitted, but where there is an Indo-Chinese population. I cannot but think that such race proclivities open up an important field of inquiry.'

Amongst papers that were read at Glasgow, a high place must be given to a most careful one by Professor Jack, 'On the Results of Five Years of Compulsory Education.'

Lord Fortescue, in his address at Plymouth, in 1877, dwelt much on the population question, avowing himself an opponent of the views of Malthus and Mill, and claiming for his leaders Mr. Chadwick and Dr. Farr. He also spoke at some length upon the imposition of what he considered needlessly high fares and rates upon goods and passengers by railway, and recalled his own opposition to the policy of Sir Robert Peel in not treating railways as monopolies, whose powers should, for the sake of the public, be carefully restricted, and he further advocated making the union, instead of the parish, the unit of English administration under a County Representative Board.

It is difficult in conducting the proceedings of this Section to hit the golden mean between being too abstract and too popular. In the year 1875 the pendulum swung perhaps a little too much to the popular direction, and subjects were discussed which were thought by some hardly compatible with the scientific character of the British Association. This led to a great deal of criticism, and in the year 1876 the question was raised—and raised by a very eminent person—whether we of Section F should continue to hold our place. The attack was able; the defence was not particularly brilliant, but the goodness of our cause or the leniency of our judges carried us through, and we were adjudged to have successfully restated the reasons for our existence. It was well, perhaps, that the question was raised, for out of this discussion came the elaborate and brilliant address—the most elaborate and brilliant to which this Section has ever listened—which was delivered at Dublin by Professor Ingram, in 1878, on the position and prospects of political economy.

Professor Ingram recapitulated the philosophical conclusions he had endeavoured to enforce, as follows:—

(1) That the study of the economic phenomena of society ought to be systematically combined with that of the other aspects of social existence. (2) That the excessive tendency to abstraction and to unreal simplifications should be checked. (3) That the *à priori* deductive method should be changed for the historical. (4) That economic laws, and the practical prescriptions founded on those laws, should be conceived and expressed in a less absolute form. 'These are, in my opinion,' he says, 'the great reforms which are required both in the conduct of economic research and in the exposition of its conclusions.' He then proceeded to say that 'If the proper study of mankind is man, the work of the Association, after the extrusion of our Section, would be like the play with the part of the protagonist left out. What appears to be the reasonable suggestion is, that the field of the Section should be enlarged, so as to comprehend the whole of sociology. The economic facts of society, as I have endeavoured to show, cannot be scientifically considered apart, and there is no reason why the researches of Sir Henry Maine, or those of Mr. Spencer, should not be as much at home here as those of Mr. Fawcett or Professor Price. Many of the subjects, too, at present included in the artificial assemblage of heterogeneous inquiries known by the name of Anthropology, really connect themselves with the laws of social development; and if our Section bore the title of the Sociological, the studies of Mr. Tylor and Sir John Lubbock, concerning the early history of civilization, would find in it their most appropriate place. I prefer the name Sociology to that of Social Science, which has been rendered indefinite in common use, and has come to be regarded as denoting a congeries of incoherent details respecting every practical matter bearing directly or remotely on public interests which happen for the moment to engage attention. There are other societies in which an opportunity is afforded for discussing such current questions in a comparatively popular arena. But if we are to be associated here with the students of the other sciences, it is our duty, as well as our interest, to aim at a genuinely scientific character in our work. Our main object should be to assist in fixing theoretic ideas on the structure, functions, and development of society. Some may regard this view of the subject with impatience, as proposing to us investigations not bearing on the great and real needs of contemporary social life. But that would be a very mistaken notion. Luciferous research, in the words of Bacon, must come before fructiferous. 'Effectual practice,' says Mr. Spencer, 'depends on superiority of ideas; methods that answer are preceded by thoughts that are true.'

In 1879 the address was delivered by Mr. Lefevre, and a most timely and useful address it was, dwelling upon the relations between our agriculturists and those of the United States with that clearness of thought, and, to use the famous Thucydidean phrase, painfulness in the search after truth, which one always expects in the writings and speeches of that very distinguished man. The address of 1880, by Mr. Hastings, has by some unfortunate accident not been printed in our annual volume.

With a view to giving you this brief sketch of the proceedings of our Section, it has been necessary for me, of course, to look through those proceedings since its foundation; and I have been led to one or two conclusions which I should like to lay before you.

In the first place, I greatly doubt whether our system of publishing epitomes of papers is a good one. These abstracts of abstracts are indeed most ghastly reading. I think it would be worth while for those who organise the business of the Section to consider next year whether it might not be better to print good papers upon local statistics in full; such will hardly in many cases have any other means of being introduced to a wider public, whereas statistical papers of more general interest may be safely left to the care of our first-born, the Statistical Society. It would be enough to mention in our annual volume that they had been read before us, without attempting an analysis which can hardly be satisfactory to the author and must be dismal to the reader.

In the second place I am inclined to think that we must adopt the policy recommended by Professor Ingram, and widen our basis, taking care at the same time to treat things scientifically, that is to say, as they are or were, and to avoid, as much as possible, dealing with them as they ought to be. The Social Science Association is better, I think, fitted than the British Association for many even good papers that have been read in this Section.

Still more imperatively necessary is it absolutely to refuse a hearing to all who wish to discuss burning questions of English politics, even although they have a scientific side. However disagreeable it may be to individuals to have to take elsewhere papers on which they may have bestowed much trouble, our first duty as a Section is to continue to exist, and we shall assuredly not continue to exist if we do not steel our hearts against their complaints.

Another great reform would, I conceive, be accomplished if the authorities of the Association were to encourage persons to read in this Section accounts of valuable works on economical and statistical subjects appearing in foreign countries.

It only remains for me to thank you for the patience with which you have listened to an address which, although I think under the circumstances necessary, has contained little or nothing that is new. I must add that I accepted the honour of presiding over this Section some months ago, and before a very considerable change had come over my life. It has been a great pleasure to me to be able to fulfil my engagement, but as I leave England next month and am necessarily very much occupied, I am sure you will forgive me if I resign the presidency of the Section into other and abler hands this afternoon.

The following Papers and Report were read:—

1. *Notes on the Village System, and the Tenure of Land in the Dravidian Villages of the Dekhan. By* Sir WALTER ELLIOT, *K.C.S.I., F.R.S.*

The increasing interest taken in Indian subjects is evidenced by the popularity of recent publications relating to them. One of the latest of these is Sir John Phear's volume on the Aryan Village. It deals with those in the north and the extreme south of Hindostan. Between these lie the Dravidian people, among whom the village system has been preserved in a still more perfect condition.

A short sketch of the Dravidian municipality is then given, and the classes of which it is composed, viz.:—

a. The village council, embracing the principal cultivating ryots.

b. The village officers.
c. The serfs or agrestial slaves.
d. The local militia.
e. The outside or foreign cultivators, who reside on sufferance.

The division of the village lands into shares is then noticed.

The incidence of the land-tax is described, as it has fluctuated under the oppressive rule of native governments; and a glance is then taken at the light thrown on the general question of normal property in the soil, which has been so well treated by Sir Henry Maine, Sir John Phear, and others.

---

2. *Report of the Anthropometric Committee.*—See Reports, p. 225.

---

3. *On the Relation of the Gold Standard in England to the International Money Market. By* Hyde Clarke, *V.P.S.S.*

Referring to his paper before the Association in 1877 on Foreign Loans, Mr. Clarke more particularly dealt with the operations of the London Money Market in connection with foreign loans and coupons. For what are called international securities, current in all the money markets of Europe, the participation of the London market is an essential feature. This becomes supreme in periods of political disquietude on the Continent, but it is partly dependent on the acceptance of the English gold standard as a fixed and unalterable standard. Whatever may be the theoretical toleration shown to bimetallism, the financial world has given in its adhesion to the gold standard. Any tampering with this is calculated to endanger our position as the central money market of the world, and to enable our rivals at Paris and elsewhere to outstrip us. He pointed out some recent incidents which were calculated to affect us. The employment of coupons as an international currency was also considered, and the connection of this market with the growing American money market.

---

4. *The Silver Question, and the Double* versus *the Single Standard. By* Wm. Westgarth.

This country is monometallic with the gold standard, which means that in our money engagements we are subject to all the incidents that may affect the value of gold. If gold happens at some time to be found very abundantly, as when California and Australia poured forth their treasures thirty years ago, the value must fall. On the other hand, if this great supply falls off, and if concurrently there is a disposition in some leading States to take preferably to a gold coinage—both of these incidents having actually happened of late—the value of gold must advance. To earn, say a thousand pounds, under the first set of circumstances may be a very different thing from earning that quantity of gold under the second set. The latter would be likely to entail a much greater labour or cost.

But yet the terms of our money engagement are clear and fair. We engage to pay or to be paid in gold, and we pay or receive accordingly, taking our chance respectively of the appreciation or depreciation for the time of that metal. With the double standard, on the other hand, there are two metals to deal with—gold and silver; and if their value, the one to the other, is exposed to fluctuation, they cannot both be fairly used as legal money, seeing that the paying party would assuredly elect to pay his creditor in that metal which for the time was relatively cheaper.

The assertion of bimetallists is that the two metals can be maintained substantially at one fixed ratio of value, if there be a sufficiently extensive bimetallic agreement for that purpose. The mints of the agreeing states have but to be kept open to unlimited coinage at the fixed ratio, and that ratio must of necessity remain substantially unchanged. In this way, the ratio of silver to gold remained substantially the same for many years, until the late large German currency operation caused the bimetallic mints to suspend their procedure, as the effect was to deplete their currencies of gold, and substitute silver to an undesirable extent. But the Paris Monetary Conference was called together by the leading bimetallic States, France and the United States, in the hope that by widening the bimetallic basis, especially by the accession of England and Germany, the new union might be strong enough to 'rehabilitate' the silver, and maintain the ratio for the future against all probable or possible incidents. The Conference has not succeeded in this object, but as it has not dissolved, but only adjourned till April next year, there seems still a prospect of at any rate the rehabilitation of the silver. The question has proved of great importance to this country from the remarkable fact that, while this country and her colonies generally have a gold standard, India, which in some sense may claim to be viewed as one half of our empire, has a silver standard.

The bimetallic view that the two metals can be kept to the one fixed ratio of value depends on the free interaction of the two currencies. If both metals are full legal money, any excess supply of the one metal will be absorbed as money of its own kind, and room made for it by extrusion of so much of the other, out of coinage into merchandise, until the said disturbing excess is balanced. In this way we perceive that the ratio of value is kept steady at the expense of the ratio of quantity. That is to say, if there should happen an unusual supply of gold, the effect would be to increase the quantity of gold coinage in the world and to diminish that of silver, and *vice versâ* with excess silver supply, while the relative value stood unchanged. But this would require that the two coinages should be in a condition of free interaction; and if they were so only to a very limited extent, the changes in relative quantity might be inconveniently extreme, as indeed the present limited bimetallic union has just of late practically experienced.

The advantage of bimetallism is that the ratio of value can be kept steady by an adequate breadth of union, and that with the larger basis of the two metals, the incidents affecting the value of either metal separately are diminished in their effect by being spread over the larger amount of the two metals.

SATURDAY, SEPTEMBER 3.

The following Papers were read:—

1. *Results to be attained by applying to the Transfer of Land in this Country the methods employed in the British Colonies. By* Sir ROBERT TORRENS, *K.C.M.G.*

---

2. *The Economic Influence of the Drinking Customs upon the Nation's Well-being. By* WILLIAM HOYLE.

MONDAY, SEPTEMBER 5.

The following Papers and Report were read:—

1. *Protection in Young Communities; Recorded Results in Victoria and New South Wales. By* GEORGE BADEN-POWELL, *M.A., F.R.A.S., F.S.S.*

(*a*) *Introductory.*—I wish to put on record, in detail, a unique case—a test case—the first that history has given us, of the actual recorded results of high and low tariffs in two similarly circumstanced communities, specially interesting because they are young communities, where, if anywhere, Protection is allowed theoretically.

Victoria and New South Wales are two of our colonies, starting ten years ago with practically similar economic environments and opportunities. Victoria has during that decade pursued a policy of Protection, and New South Wales one of Free Trade. The results are now matter of record.

(*b*) *The Details.*—These I shall briefly sum up under three heads:—

1. The *development of manufactures*, as opposed to the production of 'Colonial produce' (of food and raw material), has been, on the whole, about equal, if we look to employment of population and capital. If Protection has introduced some manufactures, Free Trade has introduced others.

2. In regard to the provision of *revenue* (the main argument), New South Wales provides a far larger general revenue per head of population. And the special revenue from customs duties has increased with the low tariff, but has barely maintained its level under the high tariff. The low tariff provides an equal amount of revenue to the high tariff, though the population is smaller.

3. In regard to *general prosperity* (industrial prosperity, social prosperity, the growth of trade, of the carrying trade, of the general wealth, and, above all, of population), New South Wales has advanced with far greater rapidity than Victoria.

(*c*) *General Results.*—1. In Victoria itself this record of what has actually taken place will greatly increase the reactionary movement in favour of a lower tariff. Signs of this are already apparent.

2. In the British Empire generally these recorded results may stimulate local Parliaments to maintain low tariffs, to the undoubted material benefit of every industrial worker throughout the Empire.

(*d*) *A Recommendation.*—I would supplement my remarks with a statement of the difficulties I encountered in my researches from the different methods sometimes adopted in the otherwise most excellent statistical records of these two Colonies. Uniformity in the method of registering statistical facts is of the utmost importance to comparative investigations. It would be of the highest advantage to secure for the future such uniformity, at all events, within the limits of the British Empire.

---

2. *Report of the Committee for inquiring into the present appropriation of Wages and Sources of Income, and considering how far it is consonant with the Economic Progress of the People of the United Kingdom.*—See Reports, p. 272.

---

3. *On the Remedies proposed for Disputes about Wages. By the* Rev. W. H. Jemison, *LL.B.*

The paper reviewed various remedies for wages disputes, including arbitration, boards of conciliation, co-operation, and industrial partnership, the last-named of which the writer described as the most hopeful, being very favourable to production, and calculated to exercise a good influence on the workpeople, though there might be difficulty in ascertaining the fixed wage and in the working of an efficient check for measuring the claim of each workman to additional pay. The plan might be helped by the adoption of a sliding scale, and, when need arises, by reference to arbitration.

---

4. *The Depression in Agriculture; its Effects and its Lessons.* By Henry F. Moore.

TUESDAY, SEPTEMBER 6.

The following Papers were read:—

1. *On the Free Public Libraries of Manchester and Notting Hill, London.* *By* James Heywood, *F.R.S.*

According to the Report of 1879–80, presented to the City Council, there are 64,079 volumes in the Reference Library situated in the Old Town Hall, Manchester, as well as a large number of newspapers, serials, periodicals, and transactions in progress.

The Reference Library is open from 10 a.m. to 9 p.m.; and on Sunday from 2 p.m. to 9 p.m.

During the year 1879–80 the number of readers were

On week-days	126,381
On Sundays	8,039
	134,420

or on an average,

406 readers on a week-day.
152 readers on a Sunday.

During the same year the number of books issued was

175,304 on week-days.
11,144 on Sundays.

186,448

or on an average,

560 books issued on each week-day, and
210 on each Sunday.

Books may be perused in the Reference Library, but are not permitted to be taken away from that collection.

There are five Lending Libraries in different parts of Manchester, to each of which a news-room is attached, and books may be perused on the premises.

Borrowers may obtain books, after signing a written agreement according to the Library regulations, in the Lending Libraries.

The books are classified under different heads: thus in the Hulme Lending Library there are 15,281 volumes, of which

754	relate to Theology and Philosophy.
4555	History, Biography.
399	Politics and Commerce.
2184	Science and Art.
4030	Literature and Polygraphy.
21	Embossed Books for the Blind.
3398	Works of Fiction.
15,341	

During the year there were 153,250 volumes lent out, and 42,236 volumes perused in the reading-room.

On Sundays there were 6,868 volumes perused, and 6,836 readers came to the Library.

During two weeks, in September 1880, there were 8,032 persons who came to the Hulme News-room, of whom there came on

Monday	1,266 persons
Tuesday	1,209 „
Wednesday	1,349 „
Thursday	1,184 „

Friday	1,277	persons
Saturday	1,144	"
Sunday	603	"
	8,030	"

or a daily average of 1,147 persons.

Reading-rooms for boys have been established at the Chorlton and Ancoats branches. In Hulme the cellar has been converted into a reading-room for boys, in which upwards of 250 boys can be accommodated at one time. The room is light, pleasant, and comfortable, and has been attended by as many juvenile readers as can be conveniently admitted.

In the Lending Libraries there were, in September 1880, 31,138 borrowers' cards in force, being an increase of 321 over the previous year.

Parcels of periodicals and papers, which have been out on the news-room tables, are made up weekly, as well as volumes not wanted, and are sent to various charitable institutions, such as the Infirmary and the Hospital for Incurables, and are also sent to the guardians of the Manchester and Chorlton Unions, for the use of the inmates of the Workhouse Hospitals, and are thankfully accepted.

Out of more than half a million of books, which have been lent out for reading, only 74 have been lost. Of these, 44 were replaced or paid for by the borrowers themselves, and 10 by guarantors.

There have been in the year, 1,991,000 visits to the Reading-rooms for the perusal of newspapers, magazines, and periodicals. There have been 966,468 books read in the year, or an average of 2,777 on each day.

The ratepayers in Manchester are contented that the money for their Free Libraries is wisely laid out.

In Notting Hill, London, a Free Library, belonging to Mr. J. Heywood, F.R.S., has been established for seven years, and contains 5,000 volumes. Of this number, in the year 1881, between January and July, there were 6,482 volumes lent out to read. During the same half-year there were in the Library

10,404 readers on week-days, and
834 readers on Sunday afternoons.

March had

2,119 readers on week-days, and
155 readers on Sunday afternoons;

and during the month of March there were

1,178 volumes lent out to read.

A borrower of books pays one penny to this Library, and either deposits half-a-crown, or gives a certificate, signed by two ratepayers, guaranteeing the safety of the volume.

---

2. *On the Progress of British Commerce in a Generation.* *By* E. J. Watherston.

The author maintained that a great mistake was commonly made by writers on 'commercial depression' by examining years when they should look to decades, and decades when they should take generations into account. Taking thirty-two years, being about a 'generation,' the total value of our exports of home produce, in 1848, was 52,849,445*l.*, being in the proportion of 1*l.* 18*s.* per head of population. In 1880 the figures were 223,060,446*l.*, or 6*l.* 9*s.* 5*d.* per head. This shows that the expansion of our foreign trade in the course of thirty-two years has been enormous. Except, perhaps, the commerce of the United States, it stands unparalleled in the history of any nation. Taking the amounts, the colonial exports augmented by about 61½ millions, while the foreign exports increased by more than 108½ millions. The total value of imports into the United Kingdom in 1854 was 152,389,053*l.*, or in proportion of 5*l.* 10*s.* 2*d.* per head of population. In 1880 the value had increased to 411,229,565*l.*, or 11*l.* 18*s.* 7*d.* per head. It is undeniable that our imports have increased at a far greater ratio than our exports of home produce. While the increase of our imports was 110 per cent., or at the rate of 5½ per cent. per annum, that of our exports was only 66 per cent., or little more than 3½ per cent. per annum. The fact of this large increase of imports, and the great preponderance of the latter over exports, appears to be the chief ground of alarm of those who lament the 'decline' of our commerce. In 1854 the imports of meat and provisions were 5,782,164*l.*, and of corn and flour 21,760,283*l.*; total, 27,542,447*l.* In 1880 the imports of meat and provisions were 32,175,326*l.*, of corn and flour 62,857,269*l.*; total, 95,032,595*l.* There could be no question whatever that the vast increase within the last twenty years in our imports has been entirely for the benefit of 'the consumer'—that is, the nation at large. We bought increasing quantities of food from foreign countries solely because the articles we wanted could be created, or manufactured, cheaper there than at home. We received over five times more meat and provisions, and over three times more corn and flour, from foreign countries in the year 1880 than in 1854. Expressed per head of population, our total food-imports averaged 18*s.* 9*d.* per head in 1854, while in 1880 the average per head was 3*l.* 17*s.* 3*d.* In other words, food has come from abroad to an increased amount represented by 2*l.* 18*s.* 6*d.* for every man, woman, and child.

The aggregate value of exports and imports (exhibiting the real progress of the nation) in 1854 was 268,210,145*l.*, or 9*l.* 14*s.* per head of population; and in 1880 697,644,031*l.*, or 20*l.* 4*s.* 10*d.* per head. In its gross amount the increase was 152 per cent., showing that there is no ground for speaking of a 'decline' in our commerce. The total commerce of this country is with over 100 foreign States and colonial possessions, more than one-half of which is carried on with six countries: first, the United States; secondly, France; thirdly, British India; fourthly, Germany; fifthly, Australasia; and sixthly, Russia. Virtually, we have but two great articles of export—namely, textile fabrics and iron, which comprise over three-fifths of our total home exports, the rest being composed of many small items. In 1868 the exports of cotton fabrics were 67,686,772*l.*, woollen 25,784,562*l.*, linen 9,548,412*l.*, and iron and steel 17,634,395*l.*, or 120,654,141*l.* out of a total of 179,677,812*l.* In 1880 the exports of cotton, woollen, and linen fabrics and iron and steel were 131,611,850*l.*, out of a total of 223,060,446*l.* The question that suggests itself in regard to this overwhelming preponderance of certain classes of our exports is, whether the causes of it be natural or artificial. It is true, our abundance of coal and of iron ore, and the perfection to which we have brought machinery, justify to some extent our profiting by these advantages. But have we not gone too far in this direction? Being the first to invent the wonderful steam machinery for working cotton fibre, flax, and wool into woven fabrics, and possessing an abundance of motive-power, we used these advantages for a considerable period with great success. But the time came when other nations competed with us in the same field, and we must not wonder if this industrial rivalry be getting more and more severe. The one remedy, and perhaps the one only, clearly offering itself, is to enlarge the field of our industrial activity. The thirteen millions' worth of silk goods we imported in 1880 came chiefly from France, which has no advantages whatever over us for manufacturing them, but the one of higher technical education of its workers, productive of greater taste. This is a matter which it is entirely in our own hands to remedy. Perhaps there are a few other things besides silk manufactures which we might with advantage produce ourselves, instead of importing them. For example, we purchase annually, chiefly from France, about 19½ million pounds' worth of butter, cheese, and eggs. At least the twelve millions' worth of butter and the five millions' worth of cheese we buy abroad we might produce ourselves, seeing how many tens of thousands of acres of land in this country are lying waste, though admirably adapted for pastures. That our farmers should allow us to import 623 millions of eggs annually is quite unexplained. We must, in order to continue progressing, do two things—namely, extend the great markets of our international trade into new regions; and extend the narrow limits of our leading manufacturing industries into wider fields. With these aims steadfastly kept in view, there is no reason why, in less than another twenty years, the sum-total of our commerce should not reach the figure of a round thousand millions.

3. *Some Results of the Removal of the Malt Tax.*[1] *By* H. Stopes.

The author commenced by a sketch of the history of the Malt Tax, pointing out its origin and recounting the arguments for its repeal urged by deputations in the Central Chamber of Commerce upon the Chancellor of the Exchequer in 1870 and 1874. He pointed out, in opposition to these, that farmers will find the repeal of the Malt Tax act more and more against their interest, because barley is no longer subject to a monopoly. The former mode of collecting the tax practically shut out the foreign barleys from the mash-tuns of the vast majority of brewers. Few but the largest brewers cared for the expensive best barleys of Germany and France. All were compelled by law to use malt or sugar, as the natural laws of fermentation made it impossible to most brewers to use only a certain percentage of sugar, usually a small one, and the rest malt. Now, all this is changed. A brewer can brew in a better way in every sense by using a proportion of other grain than malted barley. Now, too, it is very probable that large quantities of malt made abroad will be imported into this country. The result of all these causes combined must effect a heavy loss to British landowners and farmers. Maltsters as a body will in some ways lose as much as farmers. Formerly a maltster derived a good portion of his profits from skilful manipulation of the duty. This is now entirely lost to him. The competition of raw grain may prove more fatal to his interests than to the classes already mentioned. The author pointed out that the loss would only fall on those maltsters who worked unscientifically, for the others would gain by the freedom to apply the best processes in the operation. Malt will, and must, be vastly improved in manufacture and value. The malting process will get to be recognised as the most important of the first steps in the production of sound, pure beer. To brewers the change is of less importance than it would appear at first sight. The actual charge upon each quarter of malt now used by the very great majority of brewers exceeds the former charge. Then a quarter paid 22*s.* 8*d.*, inclusive of brewers' licence. Now each quarter is assumed to yield 82 lbs. gravity, and has to pay 25*s.*, less 6 per cent.; but as in most breweries, and all good ones, the yield of the malt is more than 6 per cent. greater than 82 lbs., it is fairly within bounds to assume that each quarter of malt now yields to the revenue 25*s.*, an increased charge of 2*s.* 4*d.* This money is, of course, paid by the general public. The increase does not add the large amount to the national revenue that it should do, as every quarter used by private brewers paying the 6*s.* licence only, in excess of the first quarter used, pays no duty. A large amount of beer now brewed entirely escapes duty. The power to use other materials than malt is a boon to brewers, and a national gain, notwithstanding that farmers and maltsters lose. The public get better beer, brewers make larger profits, rice merchants and maize millers are having a good time; but farmers, in obtaining what they so long desired, find that they now come into direct competition with the foreign producer in a field which the old law helped to hedge round for their especial benefit. Past experience of similar contests leaves very little room for speculation as to the result.

4. *Bankruptcy in its Economic Bearings.* *By* J. Macdonell.

5. *On Economics and Statistics, viewed from the standpoint of the Preliminary Sciences.* *By* Patrick Geddes, *F.R.S.E.*

In this paper, after pointing out the importance of uniformity in the arrangement of statistics, the schemes for that purpose proposed to the International

[1] Published *in extenso* in the *Brewer's Gazette* for September 1881.

Statistical Congress of 1878 are criticised, and a new system of classification is established in harmony with the preliminary sciences. The system is developed to a considerable extent in a series of tables, which are shown to include the facts of Political Geography, of Economic Physics, Economic Geology, Economic Botany and Zoology, of Anthropology and Demography, of Industry, Commerce, and Political Economy generally.[1] Various systems of economics are then criticised, and the paper terminates with a classification of the other papers read in the Sections of Economics and Anthropology, and a claim to have adopted the reforms of Mr. Ingram and Mr. Grant Duff.[2]

[1] 'On the Classification of Statistics,' *Proceedings Roy. Soc. Edin.* 1881.
[2] See *Nature*, September 29, 1881.

Section G.—MECHANICAL SCIENCE.

President of the Section—Sir W. Armstrong, C.B., D.C.L., LL.D., F.R.S.

THURSDAY, SEPTEMBER 1.

The President delivered the following Address:—

The astonishing progress which has been made in the construction and application of machinery during the half-century which has elapsed since the nativity of the British Association for the Advancement of Science, is a theme which I might with much complacency adopt in this address; but instead of reviewing the past and exulting in our successes, it will be more profitable to look to the future, and to dwell on our failures. It is but justice to say that by growing experience, by increased facilities of manufacture, and by the exercise of much skill and ingenuity, we have succeeded in multiplying and expanding the applications of our chief motor, the Steam Engine, to an extent that would have appeared incredible fifty years ago, but the gratulation inspired by this success is clouded by the reflection that the steam engine even in its best form remains to this day a most wasteful apparatus for converting the energy of heat into motive power. Our predecessors of that period had not the advantage of the knowledge which we possess of the true nature of heat, and the conditions and limits affecting its utilization. In their time heat was almost universally regarded as a fluid which, under the name of caloric, was supposed to lie dormant in the interstices of matter until forced out by chemical or mechanical means. Although Bacon, Newton, Cavendish, and Boyle all maintained that heat was only internal motion, and although Davy and Rumford not only held that view but proved its accuracy by experiment, yet the old notion of caloric continued to hold its ground, until in more recent times, Joule, Meyer, Codling, and others put an end to all doubt on the subject, and established the all-important fact that heat is a mode of motion having, like any other kind of motion, its exact equivalent in terms of work. By their reasonings and experiments it has been definitely proved that the quantity of heat which raises the temperature of a pound of water 1° Fahrenheit, has a mechanical value equal to lifting 772 lbs. one foot high, and that conversely the descent of that weight from that height is capable of exactly reproducing the heat expended.

The mechanical theory of heat is now universally accepted, although a remnant of the old doctrine is displayed in the continued use of the misleading term 'latent heat.' According to the new theory, heat is an internal motion of molecules capable of being communicated from the molecules of one body to those of another, the result of the imparted motion being either an increase of temperature, or the performance of work. The work may be either external, as where heat, in expanding a gas, pushes away a resisting body, or it may be internal, as where heat pulls asunder the cohering particles of ice in the process of liquefaction, or it may be partly internal and partly external, as it is in the steam engine, where the first effect of the heat is to separate the particles of water into vapour, and the second to give motion to the piston. Internal as well as external work may be reconverted into heat, but until the reconversion takes place the heat which did the work does not exist as heat, and it is delusive to call it 'latent heat.' All heat problems are comprised under the three leading ideas of internal work, external work, and temperature, and no phraseology should be used that conflicts with those ideas.

The modern theory of heat has thrown new light upon the theory of the steam engine. We now know what is the mechanical value in foot-pounds of the heat evolved in the combustion of 1 lb. of coal. In practice we can determine how much of that heat is transmitted to the water in the boiler, and we are taught how to calculate the quantity which in the process of vaporization takes the form of internal work. We can determine how much disappears in the engine in the shape of external work, including friction, and the remainder, with the exception of the trifling quantity saved in the feed water, we know to be lost. Taking a good condensing engine as an example, we may roughly say that, dividing the whole heat energy into ten equal parts, two escape by the chimney, one is lost by radiation and friction, six remain unused when the steam is discharged, and one only is realised in useful work. It may be fully admitted that the greater part of the aggregate loss is inevitable, but are we to suppose that the resources of science, ingenuity, and skill have been exhausted in the attainment of so miserable a result? Nothing but radical changes can be expected to produce any great mitigation of the present monstrous waste, and without presuming to say what measures are practicable and what are not, I will briefly point out the directions in which amelioration is theoretically possible, and shall afterwards advert to the question whether we may hope to evade the difficulties of the steam engine by resorting to electrical methods of obtaining power.

To begin with the loss which takes place in the application of heat to the boiler, why is it that we have to throw away, at the very outset of our operations, twice as much heat as we succeed in utilising in the engine? The answer is that in order to force a transmission of heat from the fire to the water in the boiler, a certain excess of temperature over that of the water must exist in the furnace and flues, and the whole of the heat below the required excess must pass away unused, except the trifling portion of it which disappears in the production of draught. Further, that since we cannot avoid admitting the nitrogen of the air along with the oxygen, we have to heat a large volume of neutral gas which has no other effect than to rob the fire. Considering what efforts have been made to facilitate the transmission of the heat by augmenting the evaporative surface, and using thin tubes as flues, it is vain to expect any great result from further perseverance in that direction, and unless a method can be devised of burning the fuel inside instead of outside the apparatus, so as to use the heated gases conjointly with the steam as a working medium in the engine, a remedy appears to be hopeless. We already practise internal combustion in the gas engine, and it is clear that with gaseous fuel at all events, we could associate such a mode of combustion with the vaporisation of water. We may even regard a gun as an engine with internally burnt fuel, and here I may remark that the action of heat in a gun is strictly analogous to that of heat in a steam engine. In both cases the heat is evolved from chemical combination, and the resulting pressures differ only in degree. The gun is the equivalent of the cylinder, and the shot of the piston, and the diagrams representing the pressure exerted in the two cases bear a close resemblance to each other. While the powder is burning in the gun we have a nearly uniform pressure, just as we have in the cylinder while the steam is entering, and in both cases the uniform pressure is followed by a diminishing pressure, represented by the usual curve of expansion. If in the steam engine we allowed the piston to be blown out, it would act as a projectile, and if in the gun we opposed mechanical resistance to the shot, we might utilize the effect in a quieter form of motive power. But it is a remarkable fact that such is the richness of coal as a store of mechanical energy, that a pound of coal, even as used in the steam engine, produces a dynamic effect about five times greater than a pound of gunpowder burnt in a gun. I cannot, however, on this account encourage the idea that steam may be advantageously substituted for gunpowder in the practice of gunnery.

And now to turn from the fire which is the birth-place of the motive energy, let us follow it in the steam, to the condenser, where most of it finds a premature tomb. From the point at which expansion commences in the cylinder the temperature and pressure of the steam begin to run down, and if we could continue to expand indefinitely, the entire heat would be exhausted, and the energy previously expended in separating the water into steam would be wholly given up in external effect; but this exhaustion would not be complete until the absolute zero of temperature was reached (viz., 461° below the zero of Fahrenheit). I do not mean to say that an ideally perfect engine necessarily involves unlimited expansion, seeing that if instead of discharging the steam at the end of a given expansion, we made the engine itself do work in compressing it, we might under the conditions of Carnot's reversible cycle, so justly celebrated as the foundation of the theory of the steam engine, recommence the action with all the unutilised heat in an available form. But an engine upon this principle could only give an amount of useful effect corresponding to the difference between the whole work done by the engine, and that very large portion of it expended in the operation of compression, and this difference viewed in relation to the necessary size of the engine, would be quite insignificant, and would in fact be wholly swallowed up in friction. Carnot did not intend to suggest a real engine, and his hypothesis therefore takes no cognizance of losses incident to the application of an actual fire to an actual boiler. His ideal engine is also supposed to be frictionless, and impervious to heat except at the point where heat has to be transmitted to the water, and there the condition of perfect conduction is assumed. In short an engine which would even approximately conform to the conditions of Carnot's cycle is an impossibility, and a perfect steam engine is alike phantom whether it be sought for in the cyclical process of Carnot, or under the condition of indefinite expansion. Practically we have to deal with a machine which, like all other machines, is subject to friction, and in expanding the steam we quickly arrive at a point at which the reduced pressure on the piston is so little in excess of the friction of the machine, as to render the steam not worth retaining, and at this point we reject it. In figurative language we take the cream off the bowl and throw away the milk. We do save a little by heating the feed water, but this gain is very small in comparison with the whole loss. What happens in the condenser is that all the remaining energy which has taken the form of internal work is reconverted into heat, but it is heat of so low a grade that we cannot apply it to the vaporization of water. But although the heat is too low to vaporize water it is not too low to vaporize ether. If instead of condensing by the external application of water, we did so by the similar application of ether, as proposed and practised by M. du Trembley twenty-five years ago, the ether would be vaporized, and we should be able to start afresh with high tension vapour, which in its turn would be expanded until the frictional limit was again reached. At that point the ether would have to be condensed by the outward application of cold water and pumped back, in the liquid state, to act over again in a similar manner. This method of working was extensively tried in France when introduced by M. du Trembley and the results were sufficiently encouraging to justify a resumption of the trials at the present time, when they could be made under much more favourable conditions. There was no question as to the economy effected, but in the discussions which took place on the subject, it was contended that equally good results might be attained by improved applications of the steam, without resorting to an additional medium. The compound engine of the present day does in fact equal the efficiency of Du Trembley's combined steam and ether engine, but there is no reason why the ether apparatus should not confer the same advantage on the modern engine that attended its application to the older form. The objections to its use are purely of a practical nature and might very possibly yield to persevering efforts at removal.

I need scarcely notice the advantage to be derived from increasing the initial pressure of the steam so as to widen the range of expansion by raising the upper limit of temperature instead of reducing the lower one. It must be remembered, however, that an increase of temperature is attended with the serious drawback of increasing the quantity of heat carried off by the gases from the fire, and also the loss by radiation, so that we have not so much to gain by increase of pressure as is commonly imagined.

But even supposing the steam engine to be improved to the utmost extent that practical considerations give us reason to hope for, we should still have to adjudge it a wasteful though a valuable servant. Nor does there appear to be any prospect of substituting with advantage any other form of thermo-dynamic engine, and thus we are led to enquire whether any other kind of energy is likely to serve us better than heat, for motive power.

Most people, especially those who are least competent to judge, look to electricity as the coming panacea for all mechanical deficiency, and certainly the astonishing progress of electricity as applied to telegraphy, and to those marvellous instruments of recent invention which the British Post Office claims to include in its monopoly of the electric telegraph, as well as the wonderful advance which electricity has made as an illuminating agent, does tend to impress us with faith in its future greatness in the realm of motive power as well.

The difference between heat and electricity in their modes of mechanical action is very wide. Heat acts by expansion of volume which we know to be a necessarily wasteful principle, while electricity operates by attraction and repulsion, and thus produces motion in a manner which is subject to no greater loss of effect than attends the motive action of gravity as exemplified in the ponderable application of falling water in hydraulic machines. If then we could produce electricity with the same facility and economy as heat, the gain would be enormous, but this, as yet at least, we cannot do. At present by far the cheapest method of generating electricity is by the dynamic process. Instead of beginning with electricity to produce power, we begin with power to produce electricity. As a secondary motor, an electric engine may, and assuredly will, play an important part in future applications of power, but our present enquiry relates to a primary, and not a secondary, employment of electricity. Thus we are brought to the question, from what source, other than mechanical action, can we hope to obtain a supply of electricity sufficiently cheap and abundant to enable it to take the place of heat as a motive energy. It is commonly said that we know so little of the nature of electricity that it is impossible to set bounds to the means of obtaining it, but ignorance is at least as liable to mislead in the direction of exaggerated expectation as in that of incredulity. It may be freely admitted that the nature of electricity is much less understood than that of heat, but we know that the two are very nearly allied. The doctrine that heat consists of internal motion of molecules may be accepted with almost absolute certainty of its truth. The old idea of heat being a separate entity is no longer held except by those who prefer the fallacious evidence of their senses to the demonstrations of science. So also the idea of electricity having a separate existence from tangible matter must be discarded, and we are justified in concluding that it is merely a strained or tensional condition of the molecules of matter. Although electricity is more prone to pass into heat, than heat into electricity, yet we know that they are mutually convertible. In short I need scarcely remind you that according to that magnificent generalisation of modern times, so pregnant with great consequences, and for which we are indebted to many illustrious investigators, we now know that heat, electricity, and mechanical action are all equivalent and transposable forms of energy, of which motion is the essence.

To take a cursory view of our available sources of energy, we have, firstly, the direct heating power of the sun's rays, which as yet we have not succeeded in applying to motive purposes. Secondly we have water power, wind power, and tidal power, all depending upon influences lying outside of our planet. And thirdly we have chemical attraction or affinity. Beyond these there is nothing worth naming. Of the radiant heat of the sun I shall have to speak hereafter, and bearing in mind that we are in search of electricity as a cause, and not an effect, of motive power, we may pass over the dynamical agencies comprised under the second head, and direct our attention to chemical affinity as the sole remaining source of energy available for our purpose. At present we derive motive power from chemical attraction through the medium of heat only, and the question is, can we with advantage draw upon the same source through the medium of electricity. The process by which we obtain our supply of heat from the exercise of affinity is that of combustion, in which the substances used consist, on the one hand, of those we call fuel, of which coal is the most important, and, on the other, of oxygen, which we derive from the atmosphere. The oxygen has an immense advantage over every other available substance in being omnipresent and costless. The only money value involved is that of the fuel, and in using coal we employ the cheapest oxidizable substance to be found in nature. Moreover the weight of coal used in the combination is only about one-third of the weight of oxygen, so that we only pay upon one-fourth of the whole material consumed. Thus we have conditions of the most favourable description for the production of energy, in the form of heat, and if we could only use the affinities of the same substances with equal facility to evolve electric energy instead of heat energy, there would be nothing more to desire; but as yet there is no appearance of our being able to do this. According to our present practice we consume zinc, instead of coal, in the voltaic production of electricity, and not only is zinc 30 or 40 times dearer than coal but it requires to be used in about sixfold larger quantity in order to develop an equal amount of energy. Some people are bold enough to say that with our present imperfect knowledge of electricity we have no right to condemn all plentiful substances, other than coal, as impractical substitutes for metallic zinc, but it is manifest that we cannot get energy from affinity, where affinity has already been satisfied. The numerous bodies which constitute the mass of our globe, and which we call earths, are bodies in this inert condition. They have already, by the union of the two elements composing them, evolved the energy due to combination, and that energy has ages ago been dissipated in space in the form of heat, never again to be available to us. As well might we try to make fire with ashes as to use such bodies over again as sources of either heat or electricity. To make them fit for our purpose we should first have to annul their state of combination, and this would require the expenditure of more energy upon them than we could derive from their recombination. Water, being oxidized hydrogen, must be placed in the same category as the earths. In short, the only abundant substances in nature possessing strong unsatisfied affinities are those of organic origin, and in the absence of coal, which is the accumulated product of a past vegetation, our supply of such substances would be insignificant. This being the case, until a means be found of making the combination of coal with oxygen directly available for the development of electric energy, as it now is of heat energy, there seems to be no probability of our obtaining electricity from chemical action at such a cost as to supplant heat as a motive agent.

But while still looking to heat as the fountain-head of our power, we may very possibly learn to transmute it, economically, into the more available form of electricity. One method of transformation we already possess, and we have every reason to believe there are others yet to be discovered. We know that when dissimilar metals are joined at opposite ends, and heated at one set of junctions while they are cooled at the other, part of the heat applied disappears in the process, and assumes the form of an electric current. Each couple of metals may be treated as the cell of a voltaic battery, and we may multiply them to any extent, and group them in series or in parallels, with the same results as are obtained by similar combinations of voltaic cells. The electricity so produced we term Thermo-electricity, and the apparatus by which the current is evolved is the thermo-electric battery. At present this apparatus is even more wasteful of heat than the steam engine, but considering the very recent origin of this branch of electrical science, and our extremely imperfect knowledge of the actions involved, we may reasonably regard the present thermo-electric battery as the infant condition of a discovery, which, if it follow the rule of all previous discoveries in electricity, only requires time to develop into great practical importance. Now if we possessed an efficient apparatus of this description we could at once apply it to the steam engine for the purpose of converting into electric energy the heat which now escapes with the rejected steam, and the gases from the fire. The vice of the steam engine lies in its inability to utilize heat of comparatively low grade, but if we could use up the leavings of the steam engine by a supplemental machine acting on thermo-electric principles, the present excessive waste would be avoided. We may even anticipate that in the distant future a thermo-electric engine may not only be used as an auxiliary, but in complete substitution of the steam engine. Such an expectation certainly seems to be countenanced by what we may observe in animated nature. An animal is a living machine dependent upon food both for its formation and its action. That portion of the food which is not used for growth or structural repair, acts strictly as fuel in the production of heat. Part of that heat goes to the maintenance of the animal temperature, and the remainder gives rise to mechanical action. The only analogy between the steam engine and this living engine is that both are dependent upon the combustion of fuel, the combustion in the one case being extremely slow, and in the other very rapid. In the steam engine the motion is produced by pressure, but in the animal machine it is effected by muscular contraction. The energy which causes that contraction, if not purely electrical, is so much of that nature that we can produce the same effect by electricity. The conductive system of the nerves is also in harmony with our conception of an electrical arrangement. In fact, a description of the animal machine so closely coincides with that of an electro-dynamic machine actuated by thermo-electricity, that we may conceive them to be substantially the same thing. At all events, the animal process begins with combustion and ends with electrical action, or something so nearly allied to it as to differ only in kind. And now observe how superior the result is in nature's engine to what it is in ours. Nature only uses heat of low grade, such as we find wholly unavailable. We reject our steam, as useless, at a temperature that would cook the animal substance, while nature works with a heat so mild as not to hurt the most delicate tissue. And yet, notwithstanding the greater availability of high grade temperature, the quantity of work performed by the living engine, relatively to the fuel consumed, puts the steam engine to shame. How all this is done in the animal organization we do not yet understand, but the result points to the attainability of an efficient means of converting low grade heat into electricity, and in striving after a method of accomplishing that object we shall do well to study nature, and profit by the excellence which is there displayed.

But it is not alone in connection with a better utilization of the heat of combustion that thermo-electricity bears so important an aspect, for it is only the want of an efficient apparatus for converting heat into electricity that prevents our using the direct heating action of the sun's rays for motive power. In our climate, it is true, we shall never be able to depend upon sunshine for power, nor need we repine on that account so long as we have the preserved sunbeams which we possess in the condensed and portable form of coal, but in regions more favoured with sun and less provided with coal the case would be different. The actual power of the sun's rays is enormous, being computed to be equal to melting a crust of ice 103 feet thick over the whole earth in a year. Within the tropics it would be a great deal more, but a large deduction would everywhere have to be made for absorption of heat by the atmosphere. Taking all things into account, however, we shall not be far from the truth in assuming the solar heat, in that part of the world, to be capable of melting annually, at the surface of the ground, a layer of ice 85 feet thick. Now let us see what this means in mechanical effect. To melt 1 lb. of ice requires 142·4 English units of heat, which, multiplied by 772, gives us 109,932 foot-pounds as the mechanical equivalent of the heat consumed in melting a pound of ice. Hence we find that the solar heat operating upon an area of one acre, in the tropics, and competent to melt a layer of ice 85 feet thick in a year, would, if fully utilized, exert the amazing power of 4,000 horses acting for nearly 9 hours every day. In dealing with the sun's energy we could afford to be wasteful. Waste of coal means waste of money, and premature exhaustion of coal-beds. But the sun's heat is poured upon the earth in endless profusion—endless at all events in a practical sense, for whatever anxiety we may feel as to the duration of coal, we need have none as to the duration of the sun. We have therefore only to consider whether we can divert to our use so much of the sun's motive energy as will repay the cost of the necessary apparatus, and whenever such an apparatus is forthcoming, we may expect to bring into subjection a very considerable proportion of the 4,000 invisible horses which Science tells us are to be found within every acre of tropical ground.

But whatever may be the future of electricity as a prime mover, either in a dominant or subordinate relation to heat, it is certain to be largely used for mechanical purposes in a secondary capacity, that is to say, as the offspring instead of the parent of motive power. The most distinctive characteristic of electricity is that which we express by the word 'current,' and this gives it great value in cases where power is required in a transmissible form. The term may be objected to as implying a motion of translation analogous to the flow of a liquid through a pipe, whereas the passage of electricity through a conductor must be regarded as a wave-like action communicated from particle to particle. In the case of a fluid current through a pipe, the resistance to the flow increases as the square of the velocity, while in the case of an electric current the resistance through a given conductor is a constant proportion of the energy transmitted. So far, therefore, as resistance is concerned, electricity has a great advantage over water for the transmission of power. The cost of the conductor will, however, be a grave consideration where the length is great, because its section must be increased in proportion to the length to keep the resistance the same. It must also be large enough in section to prevent heating, which not only represents loss, but impairs conductivity. To work advantageously on this system, a high electro-motive force must be used, and this will involve loss by imperfect insulation, increasing in amount with the length of the line. For these reasons there will be a limit to the distance to which electricity may be profitably conveyed, but within that limit there will be wide scope for its employment transmissively. Whenever the time arrives for utilizing the power of great waterfalls the transmission of power by electricity will become a system of vast importance. Even now small streams of water inconveniently situated for direct application may, by the adoption of this principle, be brought into useful operation.

For locomotive purposes also we find the dynamo-electric principle to be available, as instanced in the very interesting example presented in Siemens' electric railway, which has already attained that degree of success which generally foreshadows an important future. It forms a combined fixed engine and locomotive system of traction, the fixed engine being the generator of the power and the electric engine representing the locomotive.

Steam power may both be transmitted and distributed, by the intervention of electricity, but it will labour under great disadvantage when thus applied, until a thoroughly effective electric accumulator be provided, capable of giving out electric energy with almost unlimited rapidity. How far the secondary battery of M. Faure will fulfil the necessary conditions remains to be seen, and it is to be hoped that the discussions which may be expected to take place at this meeting of the British Association will enable a just estimate of its capabilities to be formed. The introduction of the Faure battery is at any rate a very important step in electrical progress. It will enable motors of small power, whatever their nature may be, to accomplish, by uninterrupted action, the effect of much larger machines acting for short periods, and by this means the value of very small streams of water will be greatly enhanced. This will be especially the case where the power of the stream is required for electric lighting, which, in summer, when the springs are low, will only be required during the brief hours of darkness, while in winter the long nights will be met by a more abundant supply of water. Even the fitful power of wind, now so little used, will probably acquire new life when aided by a system which will not only collect, but equalize, the variable and uncertain power exerted by the air.

It would greatly add to the utility of the Faure battery if its weight and size could be considerably reduced, for in that case it might be applicable to many purposes of locomotion. We may easily conceive its becoming available in a lighter form for all sorts of carriages on common roads, thereby saving to a vast extent the labour of horses. Even the nobler animal that strides a bicycle, or the one of fainter courage that prefers the safer seat of a tricycle, may ere long be spared the labour of propulsion, and the time may not be distant when an electric horse, far more amenable to discipline than the living one, may be added to the bounteous gifts which science has bestowed on civilized man.

In conclusion I may observe that we can scarcely sufficiently admire the profound investigations which have revealed to us the strict dynamical relation of heat and electricity to outward mechanical motion. It would be a delicate task to apportion praise amongst those whose labours have contributed, in various degrees, to our present knowledge, but I shall do no injustice in saying that of those who have expounded the modern doctrine of energy, in special relation to mechanical practice, the names of Joule, Clausius, Rankine, and William Thompson will always be conspicuous. But up to this time our knowledge of energy is almost confined to its inorganic aspect. Of its physiological action we remain in deep ignorance, and as we may expect to derive much valuable guidance from a knowledge of Nature's methods of dealing with energy in her wondrous mechanisms, it is to be hoped that future research will be directed to the elucidation of that branch of science which as yet has not even a name, but which I may provisionally term 'Animal Energetics.'

The following Paper was read:—

Observations on the Improvements of the Mississippi River, and on the proposed Ship Railway across the Isthmus of Tehuantepec, Mexico. By Captain J. B. EADS, *C.E.*

FRIDAY, SEPTEMBER 2.

The following Papers were read:—

1. *Some of the Developments of Mechanical Engineering during the last half-century. By* Sir F. J. BRAMWELL, *M.I.C.E., F.R.S.*—See Reports, p. 494.

---

2. *On the Automatic Sounder. By* JAMES DILLON, *M.I.C.E.*

In this paper the author pointed out the difficulties and delays that have now to be encountered when endeavouring accurately to prepare soundings and sections of the beds of rivers, lakes, harbours, and sea-shores, or when determining the levels or depths of existing or proposed excavations under water, and excavations and dredging operations when in progress, and lastly the difficulty in accurately ascertaining the character of the ground under water, before designing large hydraulic works, &c.

The author pointed out how he successfully overcame these various difficulties by inventing the 'Automatic Sounder.' Its construction is simple, and with it can be successfully performed the different operations referred to, with greater accuracy and at a much less expenditure of time and money, the author having tested and proved its value on very extensive hydraulic and river conservancy works.

The following is the author's description of this machine:—

There is placed across a boat, barge, or other floating substance, near stern or elsewhere, a metal or other axle-bar, called the 'central axle,' with its ends projecting a few inches over sides of boat, working freely in axle-boxes attached to sides of the boat.

Twelve or more feet (according to maximum soundings required) of a metal or other bar called the 'sounding bar,' is attached to the 'central axle,' the former hanging vertically in the water. The end of the central axle is passed through a semicircular dial resting on or near the side of the boat, the sounding bar swinging in a plane parallel to the dial and keel of the boat.

Method of Working.—When required to prepare soundings or sections for any hydraulic work—say fifty or one hundred miles of proposed river conservancy works —to a depth varying from eight to fifteen feet below the surface of the water, it is merely necessary to attach fifteen feet of a rough metal or other sounding bar to the central axle, by a thumbscrew, leaving about two feet of the sounding bar above the central axle, working in front of and pointing to the dial, placed at the side of the observer, when sitting in the stern of the boat, to note the dial-readings, when necessary, in his notebook.

On the boat being set in motion, the sounding bar (contrary to expectation) will remain hanging in the vertical position, until it meets with some obstruction or rise in the ground, when the sounding bar, working round the central axle, will be pushed from a vertical into a slanting position, and according as its end under water, resting on the ground, is raised from fifteen to less depths below the surface of the water, say to ten, five, and two feet, the other shorter end of the sounding bar will point to ten, five, and two feet on the dial. If any greater obstruction raises the lower end of the sounding bar to the surface of the water, then its upper end will point to zero on the dial.

A horizontal roll of 'section paper' is placed at back of the dial or elsewhere, kept in motion at a given rate by a simple arrangement of clockwork, or by float-boards or a screw worked by the resistance of the water when the boat is rowed or otherwise set in motion.

On the section paper is marked to scale a perfect contour line, representing the surface of the ground below water, by a pencil pointer or pen attached to the central axle, which latter is kept in motion by the rise and fall of the sounding bar firmly screwed to it.

The author, however, states that the section paper may be frequently dispensed with, and the character of the surface of the ground accurately defined by the action of the instrument under water, as more fully described in his paper. The instrument is designed to enable the observer to enter all necessary information in his notebook, three or more scales being marked on the semicircular dial, to suit sounding bars ten, twenty, or more feet in length.

---

3. *On the Economical Effect of using Cheap Gas for Gas-motors, with a description of Apparatus for producing such Gas. By* J. EMERSON DOWSON, *C.E.*

After describing what had been done by other inventors, the author gave the following particulars of his apparatus:—The retort or generator consists of a vertical cylindrical iron casing which encloses a thick lining of ganister, as in a foundry cupola, to prevent loss of heat and oxidation of the metal, and at the bottom of this cylinder is a grate on which a fire is built up. Under the grate is a closed chamber, and a jet of superheated steam plays into this and carries with it by induction a continuous current of air. The pressure of the steam forces the mixture of steam and air upwards through the fire, so that the combustion of the fuel is maintained while a continuous current of steam is decomposed, and in this way the working of the generator is constant, and the gas is produced without fluctuations in quality. The steam is produced and superheated in a zigzag coil heated by gas. The nature of the fuel required depends on the purpose for which the gas is used. If for heating boilers, furnaces, &c., coke or any kind of coal may be used; but for gas-engines, or any application of the gas requiring great cleanliness and freedom from sulphur and ammonia, it is best to use anthracite, as this does not yield condensable vapours and is very free from impurities. To produce 1,000 c. ft. only 12 lb. of anthracite are required (allowing 8 to 10% for impurities and waste) and about 7 pints of water. The cost of making the gas depends to a certain extent on the size of the generator. Experience with 16 generators has shown that the three sizes in use, producing respectively 1,000, 1,500, and 2,500 c. ft. per hour, make gas at a cost of $4\frac{1}{4}d.$, $3\frac{1}{3}d.$, and $2\frac{3}{4}d.$ per 1,000 c. ft. (including repairs, depreciation, and interest on capital outlay). Approximately the composition of the gas thus made is: Hydrogen 20%, carbon monoxide 30%, carbon dioxide 3%, and nitrogen, &c., 47% by volume. This gives about 50% by volume of combustible gases, and the calorific power of 100 litres is 155,836 gramme-units of heat. Its calorific intensity is 2,268° C. Ordinary London coal-gas of average composition has a calorific power of 559,038 gramme-units for 100 litres, so that its calorific power is about 3·5 times greater than that of the Dowson gas. Its calorific intensity is 2,554° C. The comparative explosive force of the two gases is as 3·4 : 1, *i.e.* coal-gas has 3·4 times more energy than the writer's gas; but because the combustion of the carbon monoxide proceeds at a comparatively slow rate, and because of the diluents present in the cylinder, which affect the weaker gas more than coal-gas, experience has shown that with an Otto engine it is best to allow five volumes of the Dowson gas for one volume of coal-gas. The economical result is that there is a saving of about 50% in the total working cost; and another practical consideration is that coal-gas requires 220 to 250 ℔ of coal per 1,000 c. ft. of gas, but the author's requires only 12 ℔. per 1,000 c. ft., and multiplying this by 5 to give the equivalent power of 1,000 c. ft. of coal-gas, for engine work, there is only 24 to 27% of the weight of coal required for coal-gas, and in many outlying districts this will effect an appreciable saving in the cost of transport. The results obtained by trials of this gas with a 3½ h. p. Otto engine have proved that *one h. p.* (*indicated*) *per hour is obtained with a consumption of gas derived from* 1·46 ℔. *coal*, after allowing 10% for impurities and waste of the latter. With engines of larger power the loss due to friction is proportionally less, and the consumption of gas per ind. h.p. is less: thus with a 16 h.p. (nominal) engine, which can indicate up to about 40 h.p., the consumption of coal would be only 1·2 ℔. *per ind. h.p. per hour.* A practical illustration of the relative working cost of an ordinary steam-engine of the portable type, a gas-engine driven with coal gas, and a gas-engine driven with Dowson gas (in each case indicating 30 h.p.) was given, and this showed that the gas-engine driven with Dowson gas would cost about 45½% less than with coal-gas at 3*s.* per 1,000 c. ft., and about 47½% less than the steam-engine, consuming 6 ℔. of coal per ind. h.p. per hour. The most striking feature, however, was that with the steam-engine 217 tons of coal would be required to give the same power as 39 tons of coal converted into gas by the author's process and afterwards used in a gas-engine. This represents a saving in weight of fuel of 88%. For the special reasons given it is best to allow 5 volumes of the author's gas for 1 vol. of ordinary coal-gas when worked with an Otto engine, but in all applications of the gas to heating purposes experience has shown that about 3·5 vols. of this are equal to 1 vol. of coal-gas. If, therefore, the cost of production above stated, for gas made on a small scale, be multiplied by 3·5 there will be a mean of 1*s.* as the total cost of the proved equivalent of 1,000 c. ft. of coal gas for heating purposes.

4. *On Continuous Door-locks and Footboards for Railway Carriages. By* R. Pickwell.

5. *On a new Integrating Anemometer. By the* Rev. J. M. Wilson, M.A., *and* H. S. Hele Shaw.—See Section A, p. 543.

6. *The Advantages of Ex-focal Light in first-order Dioptric Lighthouses. By* J. R. Wigham.

SATURDAY, SEPTEMBER 3.

The Section did not meet.

MONDAY, SEPTEMBER 5.

The following Papers were read:—

1. *On Telegraphic Photography.* *By* SHELFORD BIDWELL, *M.A., LL.B.*

The apparatus now explained is a development of that described in 'Nature,' February 10, 1881, and exhibited at a meeting of the Physical Society on February 26. Its purpose is to illustrate a method of transmitting pictures of natural objects by telegraph.

The receiving instrument contains a platinum-covered brass cylinder, 2 inches long and $\frac{7}{8}$ inch in diameter, mounted horizontally upon a spindle 7 inches long. One of the projecting ends of the spindle has a screw cut upon it of 64 threads to the inch; the other end is left plain. The spindle revolves in two bearings, the distance between which is equal to twice the length of the cylinder; and one of the bearings has an inside screw corresponding to that upon the spindle. A platinum point, attached to an elastic brass arm, which is fixed midway between the two bearings, presses normally upon the surface of the cylinder. The positive pole of a local battery is connected through a set of resistance coils with the platinum point, and the negative pole with the metal cylinder. If now a piece of paper which has been soaked in a solution of iodide of potassium be wrapped round the cylinder, and the cylinder be caused to rotate, the platinum point will, so long as the current passes, trace a very close spiral brown line upon the paper. When the strength of the current is diminished, the intensity of the line is enfeebled; when the current is interrupted the line is broken off, and the paper retains its original whiteness. It is evident that by regulating the intensity of the line thus traced, and introducing gaps in the proper places, any design or picture might be represented upon the paper. This is the system adopted in Bakewell's well-known copying telegraph. The author's instrument, however, differs from his in that the current is varied simply by the action of light.

At the transmitting station is a second battery, which is connected by two line wires (one of which would, in practice, be replaced by the earth) with the receiving instrument, so that the current passes through the prepared paper in the opposite direction to that of the current from the local battery. If the two currents through the paper are of equal strength they will neutralise each other, and the platinum point will make no mark when the cylinder rotates: if the current from the local battery is stronger than that from the other, the usual brown mark will appear, its intensity depending upon the difference between the strength of the two currents.

In the circuit of the second battery is introduced the transmitting instrument, the purpose of which is to regulate the current in such a manner as to produce the desired effects. The action of the transmitter depends upon the curious property of crystalline selenium, that its electrical resistance is greater in the dark than in the light. The current is caused to pass through a selenium cell, enclosed in a small rectangular box, from which all light is excluded, except such as can pass through a pinhole, drilled in the side of the box opposite to the cell. By means of a mechanical arrangement, which, though very simple, cannot easily be described without a drawing, the box is connected with a horizontal spindle in such a manner that each revolution of the spindle causes the box to move perpendicularly up and down, through a distance of 2 inches, and at the same time laterally through $\frac{1}{64}$ inch. If now a picture, not more than 2 inches square, is projected by a photographic lens upon that side of the box which contains the pinhole, it is clear that by turning the spindle the pinhole may be caused to pass successively over every point of the focussed image. The box, while moving in the upward direction, travels through space at precisely the same rate as a point on the surface of the receiving cylinder, when the spindles of the two instruments are revolving synchronously: the downward movement is rapid and is not concerned in the transmission of the picture.

To prepare the instruments for work, a piece of sensitised paper is wrapped round the cylinder of the receiver, and the platinum point pressed gently upon it: the pinhole in the transmitter is brought to the brightest part of the focussed picture, and the variable resistance in the circuit of the local battery is so adjusted that the two currents, passing through the paper in opposite directions, exactly balance each other. The cylinder and the box are then moved to their extreme positions, and all is ready to commence operations.

The two spindles are caused to revolve uniformly and synchronously. The pinhole, in the course of its up-and-down path, will cover successively every point of the projected picture, and the amount of light falling at any moment upon the selenium cell will be proportional to the illumination of that particular spot of the picture which, for the time being, is occupied by the pinhole. When the pinhole is in the dark, the resistance of the selenium cell is increased, the current from the local battery predominates, and the platinum point traces a dark brown line upon the paper; but when the pinhole happens to be passing over a bright part of the picture, the resistance of the selenium is diminished; a stronger current is then opposed to that from the local battery, and the line traced by the point is enfeebled or altogether broken. The close spiral line thus described, with the breaks in its uniformity, constitutes a picture which, if the instrument were perfect, would be a monochromatic counterpart of that projected upon the transmitter.

The pictures hitherto actually transmitted by this experimental apparatus are simple designs in black and white, painted upon glass, and projected by a magic lantern. The image of a butterfly with well-defined marks upon its wings, and a rude drawing, in broad lines, of a human face, are among the objects which have been most successfully reproduced. But with a more delicate selenium cell and more sensitive paper, there is little doubt that the efficiency of the instrument might be almost indefinitely increased.

---

2. *On the Swan Incandescent Lamp.* *By* J. W. SWAN.

---

3. *On Electric Lighting as applied to Coal Mines.* *By* ANDREW JAMIESON.

In the discussion which followed the exhibition of Swan's lamp at the Society of Telegraph Engineers in October last, Professor Tyndall remarked that probably this form of incandescent lamp could be adapted for use in coal mines as a safety lamp. Since then, two practical trials have been made with that object in view, the one at Pleasely Colliery, near Nottingham, the other at Earnock Colliery, near Glasgow. The circumstances under which the lighting has to be produced and maintained are new and different in many respects from that now being carried out above ground in our halls, houses, and open spaces. Dangers and difficulties peculiar to the situation have to be guarded against or overcome, such as explosive gases, subsiding walls or seam-roofs, continuous darkness, &c. Long lengths of leading wire have to be dealt with, involving many branches or offshoots, requiring considerable mechanical skill and still more electrical knowledge, before a suitable distribution of the eleetric current is effected, and the desired uniformity and intensity of light obtained. Particular interest is at present being manifested by mine owners, managers, and engineers to know the commercial value of the light, or, in other words, whether the possible increased light and safety of Swan's lamps over the methods hitherto adopted will result in an economy and in an increased output of coal for the same expense of labour. The author described the apparatus used at Pleasely and Earnock collieries, with models of strong miners' lanterns encasing Swan's lamps, and of airtight contact-makers of various designs and patterns, for preventing the inevitable spark (which always takes place upon disconnecting leading wires or lamps) from causing danger in a fiery mine. He pointed out that the plan of joining up a number of Swan's lamps in single parallel, with a self-exciting Gramme, Siemens, or other form of dynamo-machine, was neither the most economical nor handy for management, from the fact that the lamps required to be specially ordered and made of a slightly decreasing resistance in proportion to their distance along the main leads from the generator, and that without a costly and delicate current regulator there was considerable risk in spoiling the remaining lamps upon turning out a number of them. He said the plan of introducing an equivalent resistance to that of the lamps turned out was equivalent to throwing away so much energy, or coal, because the resistance so introduced absorbed power equal in fact to that of the lamp or lamps which it replaced. Finally, he gave several plans for joining up the lamps which, in his opinion, were more economical and better, and he stated that by using Siemens' dynamo-exciters with their alternate current machines, the danger accruing from suddenly turning out a number of lamps was avoided, as the electro-motive force remained practically constant (with low resistance leads and generator coil), and therefore the current passing the remaining lamp or lamps was always the same. For example, if 49 lamps out of 50 were suddenly switched out of circuit, the remaining lamp would not be endangered, and would have the same current passing through it and give the same light as before. He reviewed in detail the most approved mechanical and electrical apparatus for installing electric lighting in coal mines, and mentioned that he had found by experiment that good Swan lamps will give forth light at the rate of 220 candle-power per horse-power absorbed by them.

---

4. *On a Screw Gauge for Electrical Apparatus.* *By* W. H. Preece, *F.R.S.*

---

5. *On the Value of Quadriform Gaslights for Lighthouses in comparison with the Electric Light.* *By* J. R. Wigham.

TUESDAY, SEPTEMBER 6.

The following Reports and Papers were read:—

1. *Report of the Committee on Patent Legislation.*—See Reports, p. 222.

---

2. *Report of the Committee on the Steering of Screw Steamers.*

---

3. *Report of the Committee on Wind Pressure.*

---

4. *Report of the Committee on Tidal Observations in the English Channel and the North Sea.*—See Reports, p. 160.

---

5. *On some applications of Electric Energy to Horticultural and Agricultural purposes.* *By* Dr. C. Wm. Siemens, *F.R.S.*—See Reports, p. 474.

---

6. *On the Transmission of Power by Electricity.* *By* J. N. Shoolbred, *C.E.*, *F.G.S.*

7. *On the Relative Value of Incandescent Electric Lights.* *By* J. N. SHOOLBRED, *C.E.*, *F.G.S.*

---

8. *On the Society of Arts Patent Bill.* *By* Sir F. J. BRAMWELL, *M.I.C.E.*, *F.R.S.*

WEDNESDAY, SEPTEMBER 7.

The following Papers were read:—

1. *On Coal and the Abatement of Smoke in Large Towns.* *By* W. R. E. COLES.

---

2. *On British Shipping and the Tonnage Laws.* *By* Captain BEDFORD PIM, *R.N.*

---

3. *On the Pressure of Wind upon a Fixed Plane Surface.* *By* THOMAS HAWKSLEY, *C.E.*, *F.R.S.*—See Reports, p. 480.

---

4. *On a New Form of Lightning Conductor, which can be easily tested.* *By* SAMUEL VYLE.

Last year a paper was read before this Section of the British Association, drawing special attention to the great damage done to life and property by lightning, and pointing out the need that existed of periodically testing and inspecting lightning conductors, with a view to their being always kept in an efficient condition. There is, however, very great difficulty in the present method of testing conductors, it being a necessary preliminary to such test that some one be found with nerve and skill enough to carry a testing wire from the ground and connect it metallically with the top of the conductor. The electrician, having the other end of the wire below, is then in a position to commence his test. Where conductors are attached to lofty spires or high chimneys, there is both cost and danger, which is probably the reason why so few conductors are ever tested. This neglect to ascertain their condition leads to deterioration and ultimate danger, and it is more than probable fosters a widely extended belief that conductors are comparatively useless.

Recognising this difficulty in the method of testing, and noticing the emphatic utterances of scientific men as to the absolute necessity of testing lightning conductors, the author was led last year to devise a new form, which is now exhibited.

It consists of a copper cable carrying an insulated wire as its core, which wire being metallically connected with the outer cable at the top, offers a ready means of testing its condition at any time without any of the difficulty hitherto experienced in testing conductors.

Having then a wire always connected to the top of the conductor, a test can be taken when desired. This can be accomplished either on the tangent, balance, or differential principles, either of which will enable the resistance of the conductor to be ascertained. The author had adopted the latter method, the galvanometer being fitted with three keys—A, B, and C. By depressing key A on the left hand a deflection of the galvanometer needle takes place by reason of the passage of a current from the battery through one coil of the galvanometer to the insulated wire within the cable to the top, whence it descends by the latter to the earth. Unless the continuity of the testing wire and cable be good no current will pass, and the needle remains still. On depressing B a current is sent in the opposite direction through a resistance-coil to the earth. If the needle be deflected, the apparatus is proved to be ready for the resistance test, which is made by the depression of keys A and B both at the same time. The current then divides itself equally between the circuit formed by the insulated wire and conductor, and a resistance which should be made exactly equal to the other circuit; this being so, any defect in the lightning conductor would manifest itself by the needle not balancing, but showing a deflection. In such a case key C is brought into use, and its depression at the same time as B shows whether the earth of the conductor is good, or if the fault is to be looked for above ground, as the current is then divided between B and C, whose resistances are equal.

A very sensitive galvanometer needle is required, as a good conductor of average length would only be about $\frac{1}{100}$th of an ohm. One having the needle suspended by a silk fibre above, and kept in position by another such fibre below, will respond not only to $\frac{1}{100}$th of an ohm, but even to $\frac{1}{1000}$th thereof.

---

5. *On an Organisation for the Systematic Gauging of the Wells, Springs, and Rivers of Great Britain.* *By* JOSEPH LUCAS, *F.G.S.*

It has long been felt by engineers and others that there should be a survey of the sources of water-supply in this country. In the last few years several isolated observers, anticipating any general organisation on this behalf, have been registering various items of account, such as the variation in the level of water in wells, but they have never been collected and brought side by side with others, such as the rainfall, percolation, barometric pressure, and temperature, all of which influence the supply, or collated and reduced to perspective on maps, except over a very limited area in the South of England.

This very isolation, however, greatly impedes the usefulness of the work, and it is very desirable that an influential committee should be appointed to direct and systematise these separate efforts, and to take charge of the work till it is finally committed to responsible hands.

There is a committee of this Association, founded in 1874, and there is another of the Meteorological Society, at work upon underground water. Mr. Baldwin Latham has a large series of wells, springs, and rivers under observation, and there are several other observers at work in various parts of the country.

This, however, is a task too large for individuals or even societies, and should, the author thinks, be executed at the public cost. Since April last, he has been receiving returns of gaugings and other observations on surface and subterranean water-economy from observers in various parts of England, and these returns, two of which are now ready, will be published monthly till some better arrangement can be made. Until this time arrives the author will gladly receive observations from any observers of the variations in the wells, springs, and rivers of these islands, and supply proper forms, and the returns as they are published, to anyone who may take an interest in any of the various aspects of the water question.

---

6. *On a Dynamometer Coupling.* *By* Professors W. E. AYRTON, *F.R.S.*, *and* JOHN PERRY, *B.E.*—See Section A, p. 553.

---

7. *On the Lawyer's Marine Pocket Case.* *By* Capt. BEDFORD PIM, *R.N.*

INDEX.

[*An asterisk* (*) *signifies that no abstract of the communication is given.*]

OBJECTS and rules of the Association, xxv.
Places and times of meeting, with names of officers from commencement, xxxii.
List of former Presidents and Secretaries of the Sections, xxxix.
List of evening lectures, lii.
Lectures to the Operative Classes, liv.
Officers of Sectional Committees present at York, lv.
Treasurer's account, lvii.
Table showing the attendance and receipts at the annual meetings, lviii.
Officers and Council for 1881–82, lx.
Report of the Council to the General Committee at York, lxi.
Recommendations adopted by the General Committee at York:—Involving grants of money, lxiii; not involving grants of money, lxvi; communications ordered to be printed *in extenso*, lxviii; resolutions referred to the Council for consideration, lxix.
Synopsis of grants of money appropriated to scientific purposes, lxx.
Places of meeting for 1882 and 1883, lxxi.
General statement of sums which have been paid on account of grants for scientific purposes, lxxii.
General meetings, lxxxii.

Address by the President, Sir John Lubbock, Bart., M.P., F.R.S., D.C.L., LL.D., Pres. L.S., 1.

Abel (Mr.) on patent legislation, 222.
Abney (Capt.) on an investigation for the purpose of fixing a standard of white light, 126; on the present state of our knowledge of spectrum analysis, 317; on hydrocarbons in the solar atmosphere, 524; on the effect of the spectrum of silver chloride, 594.
Acetabulum of animals in which the ligamentum teres is described as wanting, Prof. Struthers on the, 720.
Actinium, the new element, Dr. T. L. Phipson on, 603.
Adams (Prof. A. Leith) on the exploration of the caves of the South of Ireland, 218.
Adams (Prof. W. G.) on an investigation for the purpose of fixing a standard of white light, 126; on standards for use in electrical measurements, 423; on magnetic disturbances and earth-currents, 463.
Africa, comparative sketch of what was known in, in 1830 with what is known in 1881, by Lieut.-Col. J. A. Grant, 746.
——, some results of fifty years' exploration in, by Rev. H. Waller, 746.
*——, the gold mines of the West Coast of, a recent visit to, Commander Cameron on, 747.
Agricultural statistics and prospects, by W. Botly, 750.
*Agriculture, the depression in; its effects and its lessons, by H. F. Moore, 761.
Alexander (Lieut.-Gen. Sir J. E.) on the improvement of freshwater fisheries, 680.
Algebra of logic, a contribution to the history of, by Rev. R. Harley, 559.
Allen (A. H.) on the separation of hydrocarbon oils from fat oils, 589.
Allen (Edward) on a remarkable human skull found near York, 704.
Allman (Prof.) on the Scottish zoological station, 177; on the occupation of a table at the zoological station at Naples, 178.
Ambresbury Banks, on excavations in a camp called, in Epping Forest, by Major-Gen. Pitt-Rivers, 697.
Anatomy and Physiology, Address by Prof. J. S. Burdon Sanderson to the Department of, 705.
Ancient dwellings, account of the discovery of six, found under and near to British barrows on the Yorkshire wolds, by J. R. Mortimer, 691.
Anderson (Dr. T.) on a prismatic optometer, 521.
Anemometer, a new integrating, Rev. J. M. Wilson and H. S. H. Shaw on, 543.

*Animism of the Indians of British Guinea, E. F. im Thurm on the, 699.
Anthropology, Address by Prof. W. H. Flower to the Department of, 682.
Anthropometric Committee, report of the, 225.
Antimonized cellular carbon galvanic battery, W. Symons on an, 557.
Archæopteryx, on a restoration of the skeleton of, with some remarks on the differences between the Berlin and London specimens, by Prof. H. G. Seeley, 618.
Arctic research, the progress of, since the foundation of the British Association, C. R. Markham on, 743.
Areas, the description of, a theorem relating to, Prof. W. W. Johnson on, 536.
*Armstrong (Prof. H. E.) on certain points in modern progress in chemical knowledge, 589.
Armstrong (Sir W.), Address by, to the Mechanical Section, 767.
Articulations of the metacarpal and metatarsal bones in man, the correspondence between the, Prof. Struthers on, 721.
Artificial flight, F. W. Brearey on, 545.
Asterosmilia Reedi, a new species of coral from the oligocene of Brockenhurst, Hants, Prof. P. M. Duncan on, 618.
Astromyelon and its root, notes on, by J. Spencer, 628.
Atchison (A. T.) on patent legislation, 222.
Atkinson (Prof. R. W.) on brewing in Japan, 585.
—— and H. Yoshida on peppermint-camphor (menthol) and some of its derivatives, 585.
Atmospheric electricity, observations of, at the Kew Observatory during 1880, G. M. Whipple on, 443.
Automatic sounder, J. Dillon on the, 774.
Axon (W. E. A.), corn or cattle: a comparison of the economic results of agriculture and cattle-raising in relation to national food-supply, 749.
Ayrton (Prof. W. E.) on experiments to determine the thermal conductivities of certain rocks, 126; on standards for use in electrical measurements, 423.
—— and Prof. J. Perry on a dynamometer coupling, 553.

Bacilli, the influence of, in the production of disease, a contribution to the question on, by Prof. J. C. Ewart, 717.
Baden-Powell (G.), protection in young communities: recorded results in Victoria and New South Wales, 760.
Baily (W. H.) on the tertiary flora of the North of Ireland, 152.
Baker (J. G.) on the botany of Madagascar, 663.
Balfour (Prof. B.) on the island of Socotra, 482.
Balfour (F. M.) on the Scottish zoological station, 177; on the occupation of a table at the zoological station at Naples, 178; on the pronephros of teleosteans and ganoids, 721.
Ball (Prof. R. S.) on observations of luminous meteors during the year 1880–81, 290; on the elucidation of a question in kinematics by the aid of non-Euclidian space, 535; on the extension of the theory of screws to the dynamics of any material system, 547.
Banking law, a general, for the United Kingdom, by W. Westgarth, 751.
*Bankruptcy in its economic bearings, by J. Macdonell, 765.
Barlow (W. H.) on patent legislation, 222.
Barometric pressure, the influence of, on the discharge of water from springs, B. Latham on, 614.
Bate (C. Spence) on the marine fauna of the southern coast of Devon and Cornwall, 198.
Becker (Miss L. E.) on the manner in which rudimentary science should be taught, and how examinations should be held therein, in elementary schools, 148.
Beddoe (Dr.) on the work of the Anthropometric Committee, 225; on the stature of the inhabitants of Hungary, 689.
Bedson (Dr. P. P.) on the method of determining the specific refraction of solids from their solutions, 155.
*Bell (I. Lowthian) on the occlusion of gaseous matter by fused silicates at high temperatures, and its possible connection with volcanic agencies, 580.
Bell (Dr. R.) on the commercial importance of Hudson's Bay, with remarks on recent surveys and investigations, 745.
*Bell and Tainter's recent researches, some of, and their consequences, W. Lant Carpenter on, 531.
Bennett (A. W.) on the colours of spring flowers, 666; on the constancy of insects in their visits to flowers, 667.
*Bertin (G.) on the origin and primitive home of the Semites, 699.
Bevan (E. J.) and C. F. Cross on cellulose and coal, 603.
Bidwell (S.) on telegraphic photography, 777.
Binaural audition, Prof. S. P. Thompson on: Part III., 565.

Binodal quartics, a class of, Prof. R. W. Genese on, 538.
Biological Section, Address by Dr. Owen to the, 651.
Birds, the foot of, P. M. C. Kermode on, and on the use of the serrated claw, 670.
——, the migration of, report on, 189.
—— which have bred in the Barnsley and South Yorkshire district, T. Lister on the, 670.
Blanford (W. T.), the Great Plain of Northern India not an old sea-basin, 638; on our present knowledge of the fauna inhabiting British India and its dependencies, 677.
Blastoidea, the structure and classification of the, P. H. Carpenter on, 634.
Blowing wells near Northallerton, the, T. Fairley on, 544; analyses of the water and gas therefrom, by T. Fairley, 601.
Blowpipe analysis, Lieut.-Col. Ross on a new system of, 598.
Bloxam (G. W.) and C. Roberts on the physical characters and proportions of the Zulus, 702.
Bonney (Prof. T. G.) on the erratic blocks of England, Wales, and Ireland, 204.
Botany of Madagascar, J. G. Baker on the, 663.
Botly (W), agricultural statistics and prospects, 750.
Bottomley (J. T.) and Prof. Sir Wm. Thomson on the illuminating powers of incandescent vacuum lamps with measured potentials and measured currents, 559.
*Bourne (F. S. A.), a journey to the Imperial mausolea east of Peking, 746.
Bourne (S.) on the manner in which rudimentary science should be taught, and how examinations should be held therein, in elementary schools, 148; on the present appropriation of wages and other sources of income, 272.
Bowkett's thermograph, W. Lant Carpenter on, 604.
Brabrook (Mr.) on the work of the Anthropometric Committee, 225.
Braham (P.) on the production of crystals by the action of metals in carbon disulphide in sealed tubes, 589.
Bramwell (Sir F. J.) on patent legislation, 222; on some of the developments of mechanical engineering during the last half-century, 494; *on the Society of Arts Patent Bill, 780.
Brearey (F. W.) on artificial flight, 545
Brewing in Japan, Prof. R. W. Atkinson on, 585.
Bridlington and Dimlington glacial shell-beds, G. W. Lamplugh on the, 616.
British commerce, the progress of, in a generation, E. J. Watherston on, 763.
*British shipping and the tonnage laws, Capt. B. Pim on, 780.
Brittain (Mr.) on the present appropriation of wages and other sources of income, 272.
*Bronze implements, certain discoveries of, in and about Leeds, J. Holmes on, 703.
Bronze socketed spears, exhibition of four, probably ancient, from China, by Prof. T. McK. Hughes, 701.
Brown (F. D.) on molecular attraction, 592.
Brown (J.) on a new electrometer, and some preliminary experiments on voltaic action, 562.
Brown (J. A. H.) on the migration of birds, 189.
Buchan (A.) *on the isothermals of the British Isles, 544; *on the diurnal period of hailstorms, *ib.*
Buchanan (J. Y.) on manganese nodules, and their occurrence on the sea-bottom, 583.
Buckland (Miss A. W.), notes on the geographical distribution of mankind, 695.
Busk (G.) on the use of the chitinous elements or appendages of the cheilostomatous polyzoa in the diagnosis of species, 662.

Calibration of mercurial thermometers by Bessel's method, Profs. T. E. Thorpe and A. W. Rücker on the, 540.
Cambrian beds of the British Isles, observations on the two types of (the Caledonian and Hiberno-Cambrian), and the conditions under which they were respectively deposited, by Prof. E. Hull, 642.
Cameron (A. G.) on the subsidences above the Permian limestone between Hartlepool and Ripon, 617.
*Cameron (Commander) on a recent visit to the gold mines of the West Coast of Africa, 747.
Campbell (Sir G.) on the work of the Anthropometric Committee, 225.
Capillary action, surface-tension and, Prof. O. Reynolds on, 524.
Carbon cells for galvanic batteries, an easy method of making, W. Symons on, 557.
Carbutt (E. H.) on patent legislation, 222.
Carpenter (Dr.) on the Scottish zoological station, 177; on the occupation of a table at the zoological station at Naples, 178.
Carpenter (P. H.) on the structure and classification of the Blastoidea, 634; on the characters of the 'Lansdown encrinite' (Millericrinus Prattii, *Gray sp.*), 635; on some permanent larval

forms among the *Crinoidea*, 671; note on the British *Comatulæ*, 672.
Carpenter (W. Lant) *on some of Bell and Tainter's recent researches and their consequences, 531; on the siliceous and other hot springs in the volcanic district of the North Island of New Zealand, 580; on Bowkett's thermograph, 604; on the hot-lake district and the glacier scenery and fjords of New Zealand, 742.
Cash (W.) on the Halifax hard seam, 626.
—— and T. Hick on a fossil stem from the Halifax coal-measures, 679.
Caves of the South of Ireland, second report on the exploration of the, 218.
Cayley (Prof.) on the calculation of tables of the fundamental invariants of algebraic forms, 55; on mathematical tables, 303; on a diagram connected with the transformation of elliptic functions, 534; a partial differential equation connected with the simplest case of Abel's theorem, *ib.*
Cefn, the caves of, near St. Asaph, North Wales, the results of recent further excavations in, by Prof. T. McK. Hughes and Mrs. Williams Wynn, 700.
Cellulose and coal, C. F. Cross and E. J. Bevan on, 603.
Celtic engravings, some late, on a slate tablet, found at Towyn, J. Park Harrison on, 701.
Change of density at the melting point, J. Love on, 564.
Cheilostomatous polyzoa, the use of the chitinous elements or appendages of the, in the diagnosis of species, G. Busk on, 662.
Chemical action between solids, Prof. T. E. Thorpe on the, 580.
Chemical affinities, note on a new method of measuring certain, by A. Tribe, 592.
*Chemical knowledge, modern progress in, Prof. H. E. Armstrong on certain points in, 589.
Chemical nomenclature, the present state of, Prof. A. W. Williamson on, 593.
Chemical Section, Prof. A. W. Williamson's Address to the, 568.
Chemico-magnetic action, some phenomena which appear to be of the nature of, W. Thomson on, 509.
Cheshire salt-field, notes on the, by C. E. De Rance, 650.
Chitinous elements or appendages of the cheilostomatous polyzoa, the use of the, in the diagnosis of species, G. Busk on, 662.
*Chlamydomyxa, notes on, by P. A. Geddes, 680.
Chrome iron ore of Japan, Prof. E. Divers on the, 587.
Clark (J. E.), glacial sections at York, and their relation to the later deposits, 614.
Clarke (Hyde) on the numerical and philological relations of the Hebrew, Phœnician, or Canaanitic alphabet and the language of the Khita inscriptions, 698; the early colonisation of Cyprus and Attica, and its relation to Babylonia, *ib.*; *exhibition of stone implements from Asia Minor, 703; on the relation of the gold standard in England to the international money market, 759.
Claw, the serrated, P. M. C. Kermode on the use of, 670.
*Climate of London, some laws which regulate the succession of mean temperature and rainfall in the, H. C. Courtney on, 544.
Climates, the effects of oceanic currents upon, Rev. Dr. Haughton on, 451.
*Coal and the abatement of smoke in large towns, W. R. E. Coles on, 780.
——, cellulose and, C. F. Cross and E. J. Bevan on, 603.
——, preliminary remarks on the microscopic structure of, by Prof. W. C. Williamson, 625.
——, the formation of, E. Wethered on, 623.
Coal-measures, the discovery of, under New Red Sandstone, and on the so-called Permian rocks of St. Helen's, Lancashire, A. Strahan on, 632.
*Cole (R. E.) on the River Gambia, 742.
*Coles (W. R. E.) on coal and the abatement of smoke in large towns, 780.
Colliery explosions, W. Galloway on, 598.
*Colour experiments, Lord Rayleigh on some, 526.
Colour-sense, the development of the, Dr. M. Lubbock on, 715.
Colza oil, the electric discharge through, A. Macfarlane on, 556.
Comatulæ, the British, note on, by P. H. Carpenter, 672.
Comet 'b' 1881, the photographic spectrum of, W. Huggins on, 520.
Cometic perihelia, the arrangement of, with reference to the sun's march in space, Dr. H. Muirhead on, 532.
Commercial geography, societies of, E. J. Watherston on, 748.
Composite portraiture, the application of, to anthropological purposes, F. Galton on, 690.
Conario-hypophysial tract, the homology of the, or of the so-called 'pineal' and 'pituitary' glands, Prof. R. Owen on, 719.
*Congruencies of the second order and second class, Dr. Hirst on, 534.
*Continuous door-locks and footboards for railway carriages, R. Pickwell on, 776.

*Cooke (Prof. J. P.), some remarks on crystallogeny, 595.
*Copper, the extraction of, J. Dixon on a process for utilising waste-products and economising fuel in, 567.
Cordeaux (J.) on the migration of birds, 189.
Corn or cattle: a comparison of the economic results of agriculture and cattle-raising in relation to national food-supply, by W. E. A. Axon, 749.
Crag, traces of man in the, by H. Stopes, 700.
Crinoidea, the permanent larval forms among the, P. H. Carpenter on, 671.
Cross (C. F.) on the hydration of salts and oxides, 602.
—— and E. J. Bevan on cellulose and coal, 603.
Crosskey (Rev. H. W.) on the erratic blocks of England, Wales, and Ireland, 204; on the circulation of underground waters, 309.
Crossley (E.) on a microscope with arrangements for illuminating the sub-stage, 563.
*Crystallogeny, some remarks on, by Prof. J. P. Cooke, 595.
Crystals, the production of, by the action of metals in carbon disulphide in sealed tubes, P. Braham on, 589.
*Cunningham (Dr. D. J.) on the structure and homologies of the suspensory ligament of the fetlock in the horse, ass, ox, sheep, and camel, 726.
Curves of double curvature, Prof. Sturm on some new theorems on, 440.
Cycloidal rotation, assumed, in arterial red discs, the causes and results of, R. W. Woollcombe on, 722.
Cyprus, the geology of the island of, R. Russell on, 640.
—— and Attica, the early colonisation of, and its relation to Babylonia, by Hyde Clarke, 698.

*Dahomey, an account of a recent visit to, by Rev. J. Milum, 747.
Dakyns (J. R.) on 'flots,' 634.
Danes and Germans, the profile of the, J. Park Harrison on, 703.
Danes' Dyke, on excavations in the earthwork called, at Flamborough, and on the earthworks of the Yorkshire wolds, by Maj.-Gen. Pitt-Rivers, 690.
Darwin (G. H.) on the measurement of the lunar disturbance of gravity, 93.
Darwin (Horace) on the measurement of the lunar disturbance of gravity, 93.
Davis (J. W.) on the exploration of a fissure in the mountain limestone at Raygill, 645; on the zoological position of the genus *Petalorhynchus*, Ag., a fossil fish from the mountain limestone, 646; on *Diodontopsodus*, Davis, a new genus of fossil fishes from the mountain limestone at Richmond, in Yorkshire, *ib.*
Dawkins (Prof. W. Boyd) on the erratic blocks of England, Wales, and Ireland, 204; on the exploration of the caves of the South of Ireland, 218.
Day (St. J. V.) on patent legislation, 222.
Deacon (G. F.) on underground temperature, 90.
Deacon (J. F.) on the phenomena of the stationary tides in the English Channel and the North Sea, and the value of tidal observations in the North Atlantic Ocean, 160.
Deane (Dr.) on the erratic blocks of England, Wales, and Ireland, 204.
*Decomposition of the elements, the alleged, Prof. Dewar on, 589.
Delany (Rev. W.) on the manner in which rudimentary science should be taught, and how examinations should be held therein, in elementary schools, 148.
De Rance (C. E.) on the erratic blocks of England, Wales, and Ireland, 204; on the circulation of underground waters, 309; notes on the Cheshire salt-field, 650.
Devono-Silurian formation, Prof. E. Hull on the, 631.
Dewar (Prof.) on the present state of our knowledge of spectrum analysis, 317; *on the alleged decomposition of the elements, 589.
—— and A. Scott on the determination of the relative atomic weights of manganese, oxygen, and silver, 596; on some vapour density determinations, 597.
Dickinson (J.) on underground temperature, 90.
Differential equation, a partial, connected with the simplest case of Abel's theorem, by Prof. Cayley, 534.
*Differential equations, a class of, Prof. Halphen on, 538.
*—— satisfied by the modular equations, Prof. H. J. S. Smith on the, 535.
*Differential resolvents, Rev. R. Harley on, 565.
*Digastric muscle, the, its modifications and its functions, G. E. Dobson on, 722.
Dillon (J.) on the automatic sounder, 774.
Dimlington glacial shell-beds, G. W. Lamplugh on the, 616.
Diodontopsodus, Davis, a new genus of fossil fishes from the mountain limestone at Richmond, in Yorkshire, J. W. Davis on, 646.
Disputes about wages, the remedies pro-

posed for, Rev. W. H. Jemison on, 761.
Divers (Prof. E.) on the sodium-alum of Japan, 586; on the occurrence of selenium and tellurium in Japan, *ib.*; on the chrome iron ore of Japan, 587.
*Dixon (J.) on a process for utilising waste-products and economising fuel in the extraction of copper, 567.
*Dobson (G. E.) on the digastric muscle, its modifications and its functions 722.
Double iodide of mercury and copper, Prof. S. P. Thompson on the, 600.
Dowkerbottom Cave, in Craven, a preliminary account of the working of, during August, 1881, by E. B. Poulton, 622.
Dowson (J. E.) on the economical effect of using cheap gas for gas-motors, with a description of apparatus for producing such gas, 775.
Dravidian villages of the Dekhan, notes on the village system, and the tenure of land in the, by Sir W. Elliot, 758.
Drift obtained from the new drainage works of Driffield, sections of the, J. R. Mortimer on, 617.
*Drinking customs, the economic influence of the, upon the nation's well-being, by W. Hoyle, 760.
Drops and capillarity, Dr. T. Woods on, 565.
Duff (Rt. Hon. M. E. Grant), Address by, to the Section of Economic Science and Statistics, 752.
Duncan (Prof. P. M.) on experiments to determine the thermal conductivities of certain rocks, 126; on fossil polyzoa, 161; on Asterosmilia Reedi, a new species of coral from the oligocene of Brockenhurst, Hants, 618.
Dunn (J. T.) on experiments to determine the thermal conductivities of certain rocks, 126.
Dynamical theory of radiation, Prof. A. Schuster on the, 561.
Dynamometer coupling, Profs. W. E. Ayrton and J. Perry on a, 553.
Dynamos, the proper proportions of resistance in the working coils, the electro-magnets, and the external circuits of, Prof. Sir Wm. Thomson on, 528.

*Eads (Capt. J. B.), observations on the improvements of the Mississippi River, and on the proposed ship railway across the Isthmus of Tehuantepec, Mexico, 774.
Ears, the function of the two, in the perception of space, Prof. S. P. Thompson on, 716.
Earth-currents, magnetic disturbances and, Prof. W. G. Adams on, 463.
Earthquake phenomena of Japan, report on the, 200.
Economic Science and Statistics, Address by the Rt. Hon. M. E. Grant Duff to the Section of, 752.
Economics and statistics viewed from the standpoint of the preliminary sciences, P. Geddes on, 765.
Economy of metal in conductors of electricity, Prof. Sir Wm. Thomson on the, 526.
Edmonds (F. B.) on the sunspot period, and planetary tides in the solar atmosphere, 544.
Electric discharge through colza oil, A. Macfarlane on the, 556.
Electric energy, some applications of, to horticultural and agricultural purposes, Dr. C. W. Siemens on, 474.
*Electric light, the value of quadriform gaslights for lighthouses in comparison with the, J. R. Wigham on, 779.
Electric lighting as applied to coal mines, A. Jamieson on, 778.
*Electric lights, incandescent, the relative value of, J. N. Shoolbred on, 780.
*Electrical apparatus, a screw gauge for, W. H. Preece on, 779.
Electrical measurements, interim report of the Committee for constructing and issuing practical standards for use in, 423.
Electrical resistances in absolute measure, account of preliminary experiments on the determination of, by Prof. G. C. Foster, 426.
Electricity, the application of, to the localisation of a bullet in a wound, W. H. Preece on, 531.
*——, the transmission of power by, J. N. Shoolbred on, 779.
*Electro-ergometer, Prof. Sir Wm. Thomson on an, 554.
Electrometer, a new, J. Brown on, and some preliminary experiments on voltaic action, 562.
——, the absolute sine, Prof. G. M. Minchin on, 558.
Elimination of sugar, the effect of the voltaic current on, W. H. Stone on, 724.
Elliot (Sir W.), notes on the village system, and the tenure of land in the Dravidian villages of the Dekhan, 758.
Elliptic functions, a diagram connected with the transformation of, Prof. Cayley on, 534.
*——, the q-series in, J. W. L. Glaisher on, 535.
*Elliptic transformation, the equation of the multiplier in the theory of, Prof. H. J. S. Smith on, 538.
Equipment, the, of exploring expeditions

now and fifty years ago, by F. Galton, 738.
Erratic blocks of England, Wales, and Ireland, ninth report on the, 204.
*Evans (Capt. Sir F. J.) on oceanic or maritime discovery, exploration, and research, 742.
Evans (Dr. John) on the exploration of the caves of the South of Ireland, 218.
Evaporation and eccentricity as co-factors in glacial periods, Rev. E. Hill on, 631.
Everett (Prof.) on underground temperature, 90.
Ewart (Prof. J. C.), a contribution to the question on the influence of bacilli in the production of disease, 717.
*Ex-focal light, the advantages of, in first order dioptric lighthouses, by J. R. Wigham, 776.

Fairley (T.) on the blowing wells near Northallerton, 544; analyses of the water and gas therefrom, 601.
Farr (Dr.) on the work of the Anthropometric Committee, 225.
Fauna, the, inhabiting British India and its dependencies, our present knowledge of, W. T. Blanford on, 677.
Faure's accumulator, some uses of, in connection with lighting by electricity, Prof. Sir Wm. Thomson on, 526.
Fellows (F. P.) on the work of the Anthropometric Committee, 225; on the present appropriation of wages and other sources of income, 272.
Ferric sulphate, the action of zinc and magnesium on acidified solutions of, Prof. T. E. Thorpe on, 595.
Field (R.) on the phenomena of the stationary tides in the English Channel and the North Sea, and the value of tidal observations in the North Atlantic Ocean, 160.
Flight (Dr. W.) on observations of luminous meteors during the year 1880–81, 290.
Flint implements, the discovery of, in stratified gravel in the Nile Valley, near Thebes, Major-Gen. Pitt-Rivers on, 693.
'Flots,' J. R. Dakyns on, 634.
Flower (Prof. W. H.), Address by, to the Department of Anthropology, 682.
*Fluid density of certain metals, Prof. W. C. Roberts and T. Wrightson on the, 582.
Foot of birds, P. M. C. Kermode on the, 670.
Forbes (Prof. G.) on the measurement of the lunar disturbance of gravity, 93.
Forbes (W. A.) on the anatomy and classification of the petrels, based upon those collected by H.M.S. 'Challenger,' 671; on a little-known cranial difference between the catarrhine and platyrrhine monkeys, 718; observations on the incubation of the Indian python (*Python molurus*), 723.
Fordham (H. G.) on the erratic blocks of England, Wales, and Ireland, 204.
*Forme biquadratique binaire ayant une même Jacobienne, les faisceaux de, C. Stephanos sur, 534.
Formule des piles, représentation graphique de la, par le Prof. C. M. Gariel, 556.
Fossil botany, researches in, by J. Spencer, 627.
Fossil fishes, a discovery of, in the New Red Sandstone of Nottingham, E. Wilson on, 637.
Fossil polyzoa, second report on, 161.
Fossil stem from the Halifax coal-measures, T. Hick and W. Cash on a, 679.
Foster (Dr. C. Le Neve) on underground temperature, 90.
Foster (Prof. G. C.) on an investigation for fixing a standard of white light, 126; on the present state of our knowledge of spectrum analysis, 317; on standards for use in electrical measurements, 423; account of preliminary experiments on the determination of electrical resistances in absolute measure, 426.
Foster (Dr. M.) on the Scottish zoological station, 177; on the occupation of a table at the zoological station at Naples, 178.
*Fox (H. C.), some laws which regulate the succession of mean temperature and rainfall in the climate of London, 544.
Free public libraries of Manchester and Notting Hill, London, J. Heywood on the, 762.
Freshwater fisheries, the improvement of, Lieut.-Gen. Sir J. E. Alexander on, 680.
Fundamental invariants of algebraic forms, the calculation of tables of the, report on, 55.

Galloway (W.) on underground temperature, 90; on colliery explosions, 598.
Galton (Capt. D.) on the phenomena of the stationary tides in the English Channel and the North Sea, and the value of tidal observations in the North Atlantic Ocean, 160; on patent legislation, 222; on the circulation of underground waters, 309.
Galton (F.) on the work of the Anthropometric Committee, 225; on the application of composite portraiture to anthropological purposes, 690 the

equipment of exploring expeditions now and fifty years ago, 738; isochronic postal charts, 740.
*Gambia, the river, R. E. Cole on, 742.
Gariel (Prof. C. M.), représentation graphique de la formule des piles, 556.
Gas, cheap, the economical effect of using, for gas-motors, with a description of apparatus for producing such gas, J. E. Dowson on, 775.
*Gaslights, quadriform, the value of, for lighthouses in comparison with the electric light, J. R. Wigham on, 779.
Gauging, the systematic, of the wells, springs, and rivers of Great Britain, J. Lucas on an organisation for, 781.
Geddes (P. A.), *notes on Chlamydomyxa, 680; *on a new sub-class of infusorians, 680; on economics and statistics viewed from the standpoint of the preliminary sciences, 765.
Geikie (Prof.) on underground temperature, 90.
Genese (Prof. R. W.) on a class of binodal quartics, 538; on involutional (1 1) correspondence, 539.
*Geodesic triangle on any surface, a property of a small, Prof. H. J. S. Smith on, 548.
Geographical distribution of mankind, notes on, by Miss A. W. Buckland, 695.
Geographical Section, Address by Sir J. D. Hooker to the, 727.
Geographical work of the Palestine Exploration Fund, Trelawney Saunders on the, 741.
Geography in Asia, the progress of, during the last fifty years, Sir R. Temple on, 741.
Geological maps, an international scale of colours for, W. Topley on, 647.
Geological Section, A. C. Ramsay's Address to the, 605.
Geology of the island of Cyprus, R. Russell on the, 640.
——, the glacial, of Central Wales, W. Keeping on, 648.
——, the subject matter of, and its classification, by Prof. W. J. Sollas, 644.
Germans, the profile of the Danes and, J. Park Harrison on, 703.
Glacial deposits of West Cumberland, J. D. Kendall on the, 617.
Glacial periods, evaporation and eccentricity as co-factors in, Rev. E. Hill on, 631.
Glacial sections at York, and their relation to the later deposits, by J. E. Clark, 614.
Gladstone (Dr. J. H.) on meteoric dust, 88; on the manner in which rudimentary science should be taught, and how examinations should be held therein, in elementary schools, 148; on the method of determining the specific refraction of solids from their solutions, 155; on the specific refraction and dispersion of light by liquids, 591.
Glaisher (J.) on underground temperature, 90; on observations of luminous meteors during the year 1880–81, 290; on mathematical tables, 303; on the circulation of underground waters, 309.
Glaisher (J. W. L.) on mathematical tables, 303; *on the q-series in elliptic functions, 535; on the general analogy between the formulæ of singly and doubly periodic functions, 548.
Gnarled series of Amlwch and Holyhead, in Anglesea, Prof. T. McK. Hughes on the, 644.
Godwin-Austen (Lieut.-Col.) on the steps taken for investigating the natural history of Socotra, 194; on the Socotran land and freshwater shells, 196.
Gold fields, the, and the quartz outcrops of Southern India, by W. King, 639.
Gold standard in England, the relation of the, to the international money market, Hyde Clarke on, 759.
Granite *in sitû*, the occurrence of, about twenty miles S.W of the Eddystone, A. R. Hunt on, 610.
Grant (Lieut.-Col. J. A.), comparative sketch of what was known in Africa in 1830 with what is known in 1881, 746.
Grant (Prof.) on the measurement of the lunar disturbance of gravity, 93.
Gray (T.) and J. Milne, a contribution to seismology, 646.
Great Plain of Northern India, the, not an old sea-basin, by W. T. Blanford, 638.
*Greenhill (A. G.) on the velocity function of a liquid due to the motion of cylinders and surfaces of revolution, 540.
Günther (Dr.) on the steps taken for investigating the natural history of Socotra, 194.

*Hailstorms, the diurnal period of, A. Buchan on, 544.
Halifax hard seam, W. Cash on the, 626.
Hall (E. H.) on the rotational coefficient in various metals, 552.
Hallett (P.) on the work of the Anthropometric Committee, 225.
Halphen (Prof.) sur un critérium de Steiner relatif à la théorie des sections coniques, 532; *on a class of differential equations, 538; on the aspects of points in a plane, *ib.*; *sur les séries hypergéométriques, 551.
Hancock (Dr. N.) on patent legislation, 222; on the present appropriation of wages and other sources of income, 272.

Harker (Allen), report on the occupation of the table at the zoological station at Naples, 182.
Harley (Rev. R.) a contribution to the history of the algebra of logic, 559; *on differential resolvents, 565.
Harris (G.) on the utilisation of the memory, 699; on the cultivation of the senses, *ib.*
Harrison (J. Park) on the work of the Anthropometric Committee, 225; *on a collection of racial photographs, 693; on some late Celtic engravings on a slate tablet found at Towyn, 701; on the profile of the Danes and Germans, 703.
Hart (S. L.) on potential due to contact, 555.
Hartlaub (Dr. G.) on the steps taken for investigating the natural history of Socotra, 194.
Hartley (Prof. W. N.) on the present state of our knowledge of spectrum analysis, 317.
Haughton (Rev. Dr.) on the calculation of sun-heat coefficients, 89; on the exploration of the caves of the South of Ireland, 218; on the effects of oceanic currents upon climates, 451; *on the effects of the lunar and solar tide in increasing the length of the sidereal day, 523.
Hawksley (T.) on the pressure of wind upon a fixed plane surface, 480.
Herschel (Prof. A. S.) on underground temperature, 90; on experiments to determine the thermal conductivities of certain rocks, 126; on observations of luminous meteors during the year 1880–81, 290.
Heywood (J.) on the manner in which rudimentary science should be taught, and how examinations should be held therein, in elementary schools, 148; on the work of the Anthropometric Committee, 225; on the free public libraries of Manchester and Notting Hill, London, 769.
Hick (T.) and W. Cash on a fossil-stem from the Halifax coal-measures, 679.
Hicks (W. M.) on recent progress in hydrodynamics: Part I., 57.
*High molecular weights, the inferences deducible from, as exhibited by the oxides of manganese, Prof. W. Odling on, 582.
Hill (Rev. E.) on evaporation and eccentricity as co-factors in glacial periods, 631.
*Hirst (Dr.) on congruencies of the second order and second class, 534.
Hobkirk (C. P.) on some points in the development of *Osmunda regalis* (Linn.), 675.
Hockin (C.) on standards for use in electrical measurements, 423.
Hodgkinson (Dr. W. R. E.) on the method of determining the specific refraction of solids from their solutions, 155.
*Holmes (J.) on certain discoveries of bronze implements in and about Leeds, 703.
*Homographies in a straight line and points in a space, a connection between, C. Stephanos on, 538.
Hooker (Sir J. D.) on the steps taken for investigating the natural history of Socotra, 194; Address by, to the Geographical Section, 727.
Hopkinson (Dr. J.) on standards for use in electrical measurements, 423.
Hopkinson (J.) on some points in the morphology of the rhabdophora, 649.
Hot-lake district, the, and the glacier scenery and fjords of New Zealand, W. Lant Carpenter on, 742.
Howlett (Rev. F.) on the general coincidence between sun-spot activity and terrestrial-magnetic disturbance, 541.
*Hoyle (W.) the economic influence of the drinking customs upon the nation's well-being, 760.
Hubrecht (Dr. A. A. W.) on the affinities of proneomenia, 673.
Hudson's Bay, the commercial importance of, Dr. R. Bell on, with remarks on recent surveys and investigations, 745.
Huggins (W.) on the photographic spectrum of comet 'b,' 1881, 520.
Hughes (Prof. T. McK.) on the erratic blocks of England, Wales, and Ireland, 204; on the Lower Cambrian of Anglesea, 643; on the gnarled series of Amlwch and Holyhead in Anglesea, 644; exhibition of a Roman bronze galeated bust, 701; exhibition of four bronze socketed spears, probably ancient, from China, *ib.*; on a supposed inscribed stone, near Llanerchymedd, in Anglesea, *ib.*
—— and Mrs. Williams Wynn, the results of recent further excavations in the caves of Cefn, near St. Asaph, North Wales, 700.
Hull (Prof. E.) on underground temperature, 90; on the circulation of underground waters, 309; on the Laurentian beds of Donegal and of other parts of Ireland, 609; on the Devono-Silurian formation, 631; observations on the two types of Cambrian beds of the British Isles (the Caledonian and Hiberno-Cambrian), and the conditions under which they were respectively deposited, 642.
Hungary, the stature of the inhabitants of, Dr. Beddoe on, 689.

Hunt (A. R.) on the occurrence of granite *in situ*, about twenty miles S.W. of the Eddystone, 610.
Huntington (Prof. A. K.) on the present state of our knowledge of spectrum analysis, 317.
Huxley (Prof.) on the Scottish zoological station, 177; on the occupation of a table at the zoological station at Naples, 178.
Hydration of salts and oxides, C. F. Cross on the, 602.
Hydrocarbon oils, the separation of, from fat oils, A. H. Allen on, 589.
Hydrocarbons in the solar atmosphere, Capt. Abney on, 524.
Hydrodynamics, report on recent progress in : Part I., 57.

Illuminating powers of incandescent vacuum lamps with measured potentials and measured currents, Prof. Sir W. Thomson and J. T. Bottomley on the, 559.
*Imperial mausolea east of Peking, a journey to the, by F. S. A. Bourne, 746.
*Im Thurm (E. F.) on the animism of the Indians of British Guiana, 699.
Indian python (*Python molurus*), observations on the incubation of the, by W. A. Forbes, 723.
Infusorial life, the arrestation of, by solar light, Prof. J. Tyndall on, 450.
*Infusorians, a new sub-class of, P. A. Geddes on, 680.
Inscribed stone, a supposed, near Llanerchymedd, in Anglesea, Prof. T. McK. Hughes on, 701.
Insect house in the gardens of the Zoological Society of London, P. L. Sclater on the, 668.
Insects, the constancy of, in their visits to flowers, A. W. Bennett on, 667.
Intra-mercurial planets, the possibility of the existence of, Balfour Stewart on, 518.
Involutional (1 1) correspondence, Prof. Genese on, 539.
Isochronic postal charts, by F. Galton, 740.
*Isothermals of the British Isles, A. Buchan on the, 544.

Jamieson (A.) on electric lighting as applied to coal mines, 778.
Japan, brewing in, Prof. R. W. Atkinson on, 585.
——, the chrome iron ore of, Prof. E. Divers on, 587.
——, the earthquake phenomena of, report on, 200.
——, the occurrence of selenium and tellurium in, Prof. E. Divers on, 586.
Japan, the sodium-alum of, Prof. E. Divers on, 586.
Jeffreys (Dr. Gwyn) on the Scottish zoological station, 177; on the occupation of a table at the zoological station at Naples, 178.
Jemison (Rev. W. H.) on the remedies proposed for disputes about wages, 761.
Jenkin (Prof. F.) on standards for use in electrical measurements, 423.
Jevons (Prof.) on the present appropriation of wages and other sources of income, 272.
Johnson (Prof. W. W.) on a theorem relating to the description of areas, 536.
Jurassic birds and their allies, by Prof. O. C. Marsh, 661.

Keeping (W.) on the glacial geology of Central Wales, 648.
Kendall (J. D.) on the glacial deposits of West Cumberland, 617.
Kermode (P. M. C.) on the foot of birds, and on the use of the serrated claw, 670.
Kinahan (G. H.) on the Laurentian rocks in Ireland, 609.
Kinematics, the elucidation of a question in, by the aid of non-Euclidian space, R. S. Ball on, 535.
King (W.) the gold fields, and the quartz outcrops of Southern India, 639.
Knowles (W. J.) on the origin and use of oval tool-stones, 692.

Lamplugh (G. W.) on the Bridlington and Dimlington glacial shell-beds, 616.
Lankester (Prof. Ray) on the Scottish zoological station, 177; on the occupation of a table at the zoological station at Naples, 178.
'Lansdown encrinite' (Millericrinus Prattii, *Gray*, *sp.*), the characters of the, P. H. Carpenter on, 635.
Latham (B.) on the influence of barometric pressure on the discharge of water from springs, 614.
Laurentian beds of Donegal and of other parts of Ireland, Prof. E. Hull on the, 609.
Laurentian rocks in Ireland, G. H. Kinahan on the, 609.
——, Irish and other, life in, C. Moore on, 610.
Laurium, Greece, some ores and minerals from, H. Stopes on, 650.
*Lawyer's marine pocket case, Captain B. Pim on the, 781.
Lebour (Prof. G. A.) on underground temperature, 90; on experiments to determine the thermal conductivities of certain rocks, 126; on the circulation of underground waters, 309.

Lee (J. E.) on the erratic blocks of England, Wales, and Ireland, 204.
Levi (Prof. L.) on the work of the Anthropometric Committee, 225; on the present appropriation of wages and other sources of income, 272.
Lewis (A. L.) on the relation of stone circles to outlying stones or tumuli or neighbouring hills, with some inferences therefrom, 697.
Light, the specific refraction and dispersion of, by liquids, Dr. J. H. Gladstone on, 591.
Lighting, a question in the theory of, Lord Rayleigh on, 526.
Lightning conductor, a new form of, which can be easily tested, S. Vyle on, 780.
Lister (T.) on the birds which have bred in the Barnsley and South Yorkshire district, 670.
Liveing (Prof.) on the present state of our knowledge of spectrum analysis, 317.
Lodge (Dr. O. J.) on standards for use in electrical measurements, 423.
Love (J.) on an overlapping spectroscope, 564; on change of density at the melting point, *ib.*
Lowe (E. J.) on observations of luminous meteors during the year 1880–81, 290.
Lower Cambrian of Anglesea, Prof. T. McK. Hughes on the, 643.
Lower Keuper Sandstone of Cheshire, A. Strahan on the, 635.
Lower Palæozoic rocks of the Craven district, J. E. Marr on some sections in the, 650.
Lubbock (Sir J.) on the manner in which rudimentary science should be taught, and how examinations should be held therein, in elementary schools, 148; on the mode in which the seed of *Stipa* buries itself in the ground, 668; on the sense of colour among some of the lower animals, 676.
Lubbock (Dr. M.) on the development of the colour-sense, 715.
Lucas (J.) on some vestiges of the ancient forest of part of the Pennine chain, 680; on an organisation for the systematic gauging of the wells, springs, and rivers of Great Britain, 781.
Luminous meteors, report on observations of, during the year 1880–81, 290.
*Lunar and solar tide, the effect of the, in increasing the length of the sidereal day, Rev. Dr. Haughton on, 523.
Lunar disturbance of gravity, the measurement of the, report on, 93.

Macadam (W. I.) on experiments with manures on the barley crop of 1881, 602.
*Macdonell (J.), bankruptcy in its economic bearings, 765.
Macfarlane (A.) on the electric discharge through colza oil, 556; an analysis of relationships, 566.
Mackintosh (D.) on the erratic blocks of England, Wales, and Ireland, 204.
McLeod (Prof.) on the present state of our knowledge of spectrum analysis, 317.
Macrory (Mr.) on patent legislation, 222.
Madagascar, the botany of, J. G. Baker on, 663.
Magnetic disturbances and earth-currents, Prof. W. G. Adams on, 463.
Mahomed (Dr. F. A.) on the work of the Anthropometric Committee, 225.
Malt tax, some results of the removal of the, by H. Stopes, 765.
Man, traces of, in the Crag, by H. Stopes, 700.
Manganese, oxygen, and silver, the determination of the relative atomic weights of, Prof. Dewar and A. Scott on, 596.
——, the oxides of, V. H. Veley on, 582.
—— nodules, and their occurrence on the sea-bottom, J. Y. Buchanan on, 583.
Mankind, notes on the geographical distribution of, by Miss A. W. Buckland, 695.
Manures, experiments with, on the barley crop of 1881, W. I. Macadam on, 602.
Marine fauna of the southern coast of Devon and Cornwall, report on the, 198.
Markham (C. R.) on the progress of Arctic research since the foundation of the British Association, 743.
Marr (J. E.) on some sections in the Lower Palæozoic rocks of the Craven district, 650.
Marsh (Prof. O. C.), Jurassic birds and their allies, 661.
Maskelyne (Prof. N. S.) on the manner in which rudimentary science should be taught, and how examinations should be held therein, in elementary schools, 148.
Mathematical and Physical Section, Address by Prof. Sir Wm. Thomson to the, 513.
Mathematical tables, report on, 303.
Mechanical engineering, some of the developments of, during the last half century, Sir F. Bramwell on, 494.
Mechanical Section, Address by Sir W. Armstrong to the, 767.
Memory, the utilisation of the, G. Harris on, 699.
Mendelejeff's table of atomic weights, W. Weldon on the first two lines of, 580.

Merrifield (C. W.) on patent legislation, 222.
Merrifield (Dr. J.) on the phenomena of the stationary tides in the English Channel and the North Sea, and the value of tidal observations in the North Atlantic Ocean, 160.
Metallic compounds containing bivalent hydrocarbon radicals, J. Sakurai on: Part II., 567.
Meteoric dust, report of the Committee appointed to collect information regarding, and to consider the question of undertaking regular observations in various localities, 88.
Microscope, a, with arrangements for illuminating the sub-stage, E. Crossley on, 563.
Migration of birds, report on the, 189.
Milne (Prof. J.) on the earthquake phenomena of Japan, 200.
—— and T. Gray, a contribution to seismology, 646.
*Milum (Rev. J.), an account of a recent visit to Dahomey, 747.
Minchin (Prof. G. M.) on the absolute sine electrometer, 558.
*Mississippi river, the improvements of the, Capt. J. B. Eads on, 774.
Molecular attraction, F. D. Brown on, 592.
Molyneux (W.) on the erratic blocks of England, Wales, and Ireland, 204; on the circulation of underground waters, 309.
Monkeys, the catarrhine and platyrrhine, a little-known cranial difference between, W. A. Forbes on, 718.
Moore (C.) on life in Irish and other Laurentian rocks, 610.
*Moore (H. F.) the depression in agriculture: its effects and its lessons, 761.
Morphology of the rhabdophora, J. Hopkinson on some points in the, 649.
Mortimer (J. R.) on sections of the drift obtained from the new drainage works of Driffield, 617; account of the discovery of six ancient dwellings, found under and near to British barrows on the Yorkshire wolds, 691.
Morton (G. H.) on the circulation of underground waters, 309.
Mountain limestone at Raygill, the exploration of a fissure in the, J. W. Davis on, 645.
Muirhead (Dr.) on standards for use in electrical measurements, 423.
Muirhead (Dr. H.) on the work of the Anthropometric Committee, 225; on the arrangement of cometic perihelia with reference to the sun's march in space, 532.
Mundesley and Westleton beds, the, the strata between the Chillesford beds and the lower boulder clay, Prof. J. Prestwich on, 620.
Mundesley and Westleton beds, the, the extension of, into Essex, Middlesex, and other inland counties, in relation to the age of certain hill-gravels and of some of the valleys of the South of England, Prof. J. Prestwich on, 620.

New Red Sandstone of Nottingham, a discovery of fossil fishes in the, E. Wilson on, 637.
Newton (Prof.) on the migration of birds, 189.
New Zealand, the siliceous and other hot springs in the volcanic district of the North Island of, W. Lant Carpenter on, 580.
——, the hot-lake district and the glacier scenery and fjords of, W. Lant Carpenter on, 742.
Nitric ferment, alterations in the properties of the, by cultivation, R. Warington on, 593.
Numeral and philological relations of the Hebrew, Phœnician, or Canaanitic alphabet and the language of the Khita inscriptions, Hyde Clarke on the, 698.

*Occlusion of gaseous matter by fused silicates at high temperatures, and its possible connection with volcanic agencies, I. Lowthian Bell on the, 580.
*Occultation of stars, of the first and other bright magnitudes, the desirability of observing, from places where they are to be seen near the horizon, H. S. Williams on, 547.
Oceanic currents, the effects of, upon climates, Rev. Dr. Haughton on, 451.
*Oceanic or maritime discovery, exploration, and research, Capt. Sir F. J. Evans on, 742.
*Odling (Prof. W.) on the inferences deducible from high molecular weights, as exhibited by the oxides of manganese, 582.
Osmunda regalis (Linn.), some points in the development of, C. P. Hobkirk on, 675.
Oval tool-stones, the origin and use of, W. J. Knowles on, 692.
Owen (Dr. R.), Address by, to the Biological Section, 651; on the homology of the conario-hypophysial tract, or of the so-called 'pineal' and 'pituitary' glands, 719.
Oxides of manganese, V. H. Veley on the, 582.

Palæozoic rocks of North Devon and West Somerset, W. A. E. Usher on the, 629.

Palestine Exploration Fund, the geographical work of the, Trelawney Saunders on, 741.
Papuans and the Polynesians, C. S. Wake on the, 696.
Parker (J.) on the circulation of underground waters, 309.
*Patent Bill, the Society of Arts, Sir F. J. Bramwell on, 780.
Patent legislation, report on, 222.
Pengelly (W.) on underground temperature, 90; on the erratic blocks of England, Wales, and Ireland, 204; on the circulation of underground waters, 309.
Pennine chain, some vestiges of the ancient forest of part of the, J. Lucas on, 680.
Penrose (F. G.), report on the occupation of the table at the zoological station at Naples, 183.
Peppermint-camphor (menthol) and some of its derivatives, Prof. R. W. Atkinson and H. Yoshida on, 585.
Periodic functions, singly and doubly, the general analogy between the formulæ of, J. W. L. Glaisher on, 548.
Perry (Prof. J.) on experiments to determine the thermal conductivities of certain rocks, 126; on standards for use in electrical measurements, 423.
—— and Prof. W. E. Ayrton on a dynamometer coupling, 553.
Petalorhynchus, Ag., the zoological position of the genus, a fossil fish from the mountain limestone, J. W. Davis on, 646.
Petrels, the anatomy and classification of the, based upon those collected by H.M.S. 'Challenger,' W. A. Forbes on, 671.
Petrie (W. F.), notes on some specimens of saw-cuts and drill-holes in hard stones of primeval Egyptian period, 697.
Phené (Dr.) on Scandinavian and Pictish customs on the Anglo-Scottish border, 693; on some objects recently exhumed in Britain, of apparently Phœnician origin, 695.
Phipson (Dr. T. L.) on the new element, actinium, 603.
Phœnician origin, some objects of apparently, recently exhumed in Britain, Dr. Phené on, 695.
Phosphates of lime and ammonia, note on the, by J. A. Wanklyn, 597.
Photographic spectrum of comet 'b' 1881, W. Huggins on the, 520.
*Photometry, Prof. Sir Wm. Thomson on, with experiments, 561.
Physical Section, Address by Prof. Sir Wm. Thomson to the Mathematical and, 513.
Physiology, Anatomy and, Address by Prof. J. S. Burdon Sanderson to the Department of, 705.
*Pickwell (R.) on continuous door-locks and footboards for railway carriages, 776.
Pictish and Scandinavian customs on the Anglo-Scottish border, Dr. Phené on, 693.
Pim (Capt. B.) *on British shipping and the tonnage laws, 780; *on the lawyer's marine pocket case, 781.
Pitt-Rivers (Maj.-Gen.) on the work of the Anthropometric Committee, 225; on excavations in the earthwork called Danes' Dyke at Flamborough, and on the earthworks of the Yorkshire wolds, 690; on the discovery of flint implements in stratified gravel in the Nile Valley, near Thebes, 693; on excavations in a camp called Ambresbury Banks in Epping Forest, 697.
Plant (J.) on the erratic blocks of England, Wales, and Ireland, 204; on the circulation of underground waters, 309.
Plesiosauria, Simosaurus pusillus (Fraas), a step in the evolution of the, Prof. H. G. Seeley on, 618.
*Points in a plane, the aspects of Prof. Halphen on, 538.
*Points in a space, a connection between homographies in a straight line and, C. Stephanos on, 538.
*Polar planes of a point with respect to four quadric surfaces, W. Spottiswoode on the, 547.
Polarising prism, a new, Prof. S. P. Thompson on, 563.
Polynesians and the Papuans, C. S. Wake on the, 696.
Potential due to contact, S. L. Hart on, 555.
Poulton (E. B.), a preliminary account of the working of Dowkerbottom Cave, in Craven, during August, 1881, 622.
Preece (W. H.) on standards for use in electrical measurements, 423; on the application of electricity to the localisation of a bullet in a wound, 531; *on a screw-gauge for electrical apparatus, 779.
Pressure of wind upon a fixed plane surface, T. Hawkley on the, 480.
Prestwich (Prof. J.) on the erratic blocks of England, Wales, and Ireland, 204; on the circulation of underground waters, 309; some observations on the causes of volcanic action, 610; on the strata between the Chillesford beds and the lower boulder clay, 'The Mundesley and the Westleton beds,' 620; on the extension into Essex, Middlesex, and other inland counties, of the Mundesley and Westleton beds,

in relation to the age of certain hill-gravels and of some of the valleys of the South of England, *ib.*
Prismatic optometer, Dr. T. Anderson on a, 521.
Proneomenia, the affinities of, Dr. A. A. W. Hubrecht on, 673.
Pronephros of teleosteans and ganoids, F. M. Balfour on the, 721.
Proportions of resistance, the proper, in the working coils, the electro-magnets, and the external circuits of dynamos, Prof. Sir Wm. Thomson on, 528.
Protection in young communities: recorded results in Victoria and New South Wales, by G. Baden-Powell, 760.
Purser (Prof.) on the measurement of the lunar disturbance of gravity, 93.
Pye-Smith (Mr.) on the Scottish zoological station, 177.

*Quadratic surds, a linear relation between two, Prof. H. J. S. Smith on, 538.

*Racial photographs, a collection of, J. Park Harrison on, 693.
Radiation, the dynamical theory of, Prof. A. Schuster on, 561.
Rainfall observations made upon York Minster by Prof. John Phillips, F.R.S., G. J. Symons on the, 551.
Ramsay (Prof. A. C.) on underground temperature, 90; on the earthquake phenomena of Japan, 200; Address by, to the Geological Section, 605.
Rawson (Sir R.) on the work of the Anthropometric Committee, 225.
Rayleigh (Lord) on the present state of our knowledge of spectrum analysis, 317; on standards for use in electrical measurements, 423; *some colour experiments, 526; on a question in the theory of lighting, *ib.*
Reinold (Prof.) on the present state of our knowledge of spectrum analysis, 317.
Relationships, an analysis of, by A. Macfarlane, 566.
*Représentation des rotations autour d'un point par des points de l'espace, C. Stephanos sur la, 547.
Reynolds (Prof. E.) on the present state of our knowledge of spectrum analysis, 317.
Reynolds (Prof. O.) on the phenomena of the stationary tides in the English Channel and the North Sea, and the value of tidal observations in the North Atlantic Ocean, 160; on surface-tension and capillary action, 524.
Rhabdophora, some points in the morphology of the, J. Hopkinson on, 649.
Rhætics of Nottinghamshire, E. Wilson on the, 637.
Roberts (C.) on the work of the Anthropometric Committee, 225.
—— and G. W. Bloxam on the physical characters and proportions of the Zulus, 702.
Roberts (I.) on the circulation of underground waters, 309.
Roberts (Prof. W. C.) on the present state of our knowledge of spectrum analysis, 317.
*—— and T. Wrightson on the fluid density of certain metals, 582.
Rolleston (Prof.) on the Scottish zoological station, 177; on the occupation of a table at the zoological station at Naples, 178; on the work of the Anthropometric Committee, 225.
Roman bronze galeated bust, exhibition of a, by Prof. T. McK. Hughes, 701.
Roscoe (Prof.) on meteoric dust, 88; on the reducing action of zinc and magnesium on vanadium solutions, 596.
Ross (Lieut.-Col.) on a new system of blowpipe analysis, 598.
Rotational coefficient in various metals, E. H. Hall on the, 552.
Rowe (J. B.) on the marine fauna of the southern coast of Devon and Cornwall, 198.
Rücker (Prof. A. W.) on a problem in stream lines, 554.
—— and Prof. T. E. Thorpe on the calibration of mercurial thermometers by Bessel's method, 540.
Rudimentary science, report on the manner in which it should be taught in elementary schools, and how examinations should be held therein, 148.
Russell (R.) on the geology of the island of Cyprus, 640.

Sakurai (J.) on metallic compounds containing bivalent hydrocarbon radicals: Part II., 567.
Salmon (Prof.) on the calculation of tables of the fundamental invariants of algebraic forms, 55.
Sanderson (Prof. J. S. Burdon), Address by, to the Department of Anatomy and Physiology, 705.
Saunders (H.) on the natural history of Timor-laut, 197.
Saunders (Trelawney) on the geographical work of the Palestine Exploration Fund, 741.
Saw-cuts and drill-holes in hard stones of primeval Egyptian period, notes on some specimens of, by W. F. Petrie, 697.
Scandinavian and Pictish customs on the Anglo-Scottish border, Dr. Phené on, 693.
Schuster (Prof. A.) on meteoric dust, 88; on the present state of our knowledge

of spectrum analysis, 317; on the dynamical theory of radiation, 561.
Sclater (P. L.) on the occupation of a table at the zoological station at Naples, 178; on the steps taken for investigating the natural history of Socotra, 194; on the natural history of Timor-laut, 197; on the insect-house in the gardens of the Zoological Society of London, 668.
Scott (A.) and Prof. Dewar on the determination of the relative atomic weights of manganese, oxygen, and silver, 596; on some vapour density determinations, 597.
Scottish zoological station, report of the Committee appointed to aid in the maintenance of the, 177.
*Screw-gauge for electrical apparatus, W. H. Preece on a, 779.
*Secondary battery, an early attempt at a, Dr. C. W. Siemens on, 554.
Sections coniques, un critérium de Steiner relatif à la théorie des, M. Halphen sur, 532.
Seebohm (Mr.) on the steps taken for investigating the natural history of Socotra, 194.
Seeley (Prof. H. G.) on Simosaurus pusillus (Fraas), a step in the evolution of the plesiosauria, 618; on a restoration of the skeleton of Archæopteryx, with some remarks on the differences between the Berlin and London specimens, *ib.*
Seismology, a contribution to, by J. Milne and T. Gray, 646.
Selenium and tellurium, the occurrence of, in Japan, Prof. E. Divers on, 586.
*Semites, the origin and primitive home of the, by G. Bertin, 699.
Sense of colour among some of the lower animals, Sir J. Lubbock on the, 676
Senses, the cultivation of the, G. Harrison, 699.
*Séries hypergéométriques, Prof. Halphen sur les, 551.
Serrated claw, the use of the, P. M. C. Kermode on, 670.
Shaen (W.), on the manner in which rudimentary science should be taught, and how examinations should be held therein, in elementary schools, 148.
Shaw (H. S. H.) and Rev. J. M. Wilson, on a new integrating anemometer, 543.
*Ship railway across the Isthmus of Tehuantepec, Mexico, Capt. J. B. Eads on the, 774.
Shoolbred (J. N.) on the phenomena of the stationary tides in the English Channel and the North Sea, and the value of tidal observations in the North Atlantic Ocean, 160; *on the transmission of power by electricity, 779; *on the relative value of incandescent electric lights, 780.
*Sidereal day, the effects of the lunar and solar tide in increasing the length of the, Rev. Dr. Haughton on, 523.
Siemens (Dr. C. W.) on the measurement of the lunar disturbance of gravity, 93; on patent legislation, 222; on some applications of electric energy to horticultural and agricultural purposes, 474; *on an early attempt at a secondary battery, 554.
Siliceous and other hot springs in the volcanic district of the North Island of New Zealand, W. Lant Carpenter on the, 580.
Silver chloride, the effect of the spectrum of, Capt. Abney on, 594.
Silver question, the, and the double *versus* the single standard, by W. Westgarth, 759.
Simosaurus pusillus (Fraas), a step in the evolution of the plesiosauria, Prof. H. G. Seeley on, 618.
Skull, a remarkable human, found near York, E. Allen on, 704.
Sladen (P.) on the Scottish zoological station, 177; on the occupation of a table at the zoological station at Naples, 178.
Smith (Mr. Dew) on the occupation of a table at the zoological station at Naples, 178.
Smith (Prof. H. J. S.) on mathematical tables, 303; *on the differential equations satisfied by the modular equations, 535; *on the equation of the multiplier in the theory of elliptic transformation, 538; *on a linear relation between two quadratic surds, *ib.*; *on a property of a small geodesic triangle on any surface, 548.
*Society of Arts Patent Bill, Sir F. J. Bramwell on the, 780.
Socotra, the island of, Prof. B. Balfour on, 482.
——, the natural history of, report on the steps taken for investigating, 194.
Socotran land and freshwater shells, report on, by Lieut.-Col. H. H. Godwin-Austen, 196.
Sodium-alum of Japan, Prof. E. Divers on the, 586.
Solar atmosphere, hydrocarbons in the, Capt. Abney on, 524.
Sollas (Prof. W. J.) on the connection between the intrusion of volcanic rock and volcanic eruptions, 613; the subject-matter of geology, and its classification, 644.
Specific refraction of solids, report on the method of determining the, from their solutions, 155.

Spectroscope, an overlapping, J. Love on, 564.
Spectrum analysis, report on the present state of our knowledge of, 317.
Spectrum of silver chloride, the effect of, Capt. Abney on, 594.
Spencer (J.), researches in fossil botany, 627; notes on astromyelon and its root, 628.
*Spottiswoode (W.) on the polar planes of a point with respect to four quadric surfaces, 547.
Spring flowers, the colours of, A. W. Bennett on, 666.
Statistics and economics viewed from the standpoint of the preliminary sciences, P. Geddes on, 765.
Statistics, Economic Science and, Address by the Rt. Hon. M. E. Grant Duff to the Section of, 752.
Steiner, un critérium de, relatif à la théorie des sections coniques, M. Halphen sur, 532.
Stephanos (C.) *sur les faisceaux de forme biquadratique binaire ayant une même Jacobienne, 534; *on a connection between homographies in a straight line and points in a space, 538; *sur la représentation des rotations autour d'un point par des points de l'espace, 547.
Stewart (Balfour) on the possibility of the existence of intra-mercurial planets, 518.
Stipa, the mode in which the seed of, buries itself in the ground, Sir J. Lubbock on, 668.
Stokes (Prof. G. G.) on mathematical coal tables, 303.
Stone (J. Harris), the viking's ship, discovered at Sandefjord in Norway, 1880, 689.
Stone (W. H.) on the effect of the voltaic current on the elimination of sugar, 724.
Stone circles, the relation of, to outlying stones or tumuli or neighbouring hills, with some inferences therefrom, A. L. Lewis on, 697.
*Stone implements from Asia Minor, exhibition of, by Hyde Clarke, 703.
Stoney (Mr.) on the present state of our knowledge of spectrum analysis, 317.
Stooke (S.) on the circulation of underground waters, 309.
Stopes (H.) on some ores and minerals from Laurium, Greece, 650; traces of man in the Crag, 700; some results of the removal of the malt tax, 765.
Strahan (A.) on underground temperature, 90; on the discovery of coal-measures under New Red Sandstone, and on the so-called Permian rocks of St. Helen's, Lancashire, 632; on the Lower Keuper Sandstone of Cheshire, 635.
Stream lines, a problem in, Prof. A. W. Rücker on, 554.
Struthers (Prof.) on the acetabulum of animals in which the ligamentum teres is described as wanting, 720; on the correspondence between the articulations of the metacarpal and metatarsal bones in man, 721.
Sturm (Prof.) on some new theorems on curves of double curvature, 440.
Subsidences above the Permian limestone between Hartlepool and Ripon, A. G. Cameron on the, 617.
Sun-heat coefficients, second report on the calculation of, 89.
Sunshine recorder stand, a universal, G. M. Whipple on, 540.
Sunspot activity and terrestrial magnetic disturbance, the general coincidence between, Rev. F. Howlett on, 541.
Sunspot period, the, and planetary tides in the solar atmosphere, F. B. Edmonds on, 544.
Surface-tension and capillary action, Prof. O. Reynolds on, 524.
*Suspensory ligament of the fetlock of the horse, ass, ox, sheep, and camel, the structure and homologies of the, Dr. D. J. Cunningham on, 726.
*Swan (J. W.) on the Swan incandescent lamp, 778.
Sylvester (Prof.) on the calculation of tables of the fundamental invariants of algebraic forms, 55.
Symons (G. J.) on underground temperature, 90; on the circulation of underground waters, 309; on the rainfall observations made upon York Minster by Prof. John Phillips, F.R.S., 551.
Symons (W.) on an easy method of making carbon cells for galvanic batteries, 557; on an antimonized cellular carbon galvanic battery, *ib.*

Tait (Prof.) on the measurement of the lunar disturbance of gravity, 93.
Tawney (E. B.) on the Upper Bagshot Sands of Hordwell Cliff, Hampshire, 633.
Taylor (H.) on standards for use in electrical measurements, 423; on the causes of the variation in the temperature-coefficient of the alloys of platinum and silver, 431.
Telegraphic photography, S. Bidwell on, 777.
Tellurium and selenium, the occurrence of, in Japan, Prof. E. Divers on, 586.
Temperature-coefficient of the alloys of platinum and silver, H. Taylor on the causes of the variation of the, 431.

Temple (Sir R.) on the progress of geography in Asia during the last fifty years, 741.
Terrestrial magnetic disturbance, the general coincidence between sunspot activity and, Rev. F. Howlett on, 541.
Terrill (W.) on the erratic blocks of England, Wales, and Ireland, 204
Tertiary flora of the North of Ireland, third report on the, 152.
Theory of screws, the extension of the, to the dynamics of any material system, R. S. Ball on, 547.
Thermal conductivities of certain rocks, final report on experiments to determine the, showing especially the geological aspects of the investigation, 126.
Thermograph, Bowkett's, W. Lant Carpenter on, 604.
Thiselton-Dyer (Mr.) on the natural history of Timor-laut, 197.
Thompson (Prof. S. P.) on the manner in which rudimentary science should be taught, and how examinations should be held therein, in elementary schools, 148; on the electric conductivity and dichroic absorption of tourmaline, 531; on volta-electric inversion, 552; on a new polarising prism, 563; on binaural audition: Part III., 565; on the double iodide of mercury and copper, 600; on the function of the two ears in the perception of space, 716.
Thomson (Sir C. Wyville) on the Scottish zoological station, 177; on the occupation of a table at the zoological station at Naples, 178.
Thomson (Prof. Sir Wm.) on meteoric dust, 88; on underground temperature, 90; on the measurement of the lunar disturbance of gravity, 93; on the phenomena of the stationary tides in the English Channel and the North Sea, and the value of tidal observations in the North Atlantic Ocean, 160; on patent legislation, 222; on mathematical tables, 303; on standards for use in electrical measurements, 423; Address by, to the Mathematical and Physical Section, 513; on some uses of Faure's accumulator in connection with lighting by electricity, 526; on the economy of metal in conductors of electricity, *ib.*; on the proper proportions of resistance in the working coils, the electro-magnets, and the external circuits of dynamos, 528; *on an electro-ergometer, 554; *on photometry, with experiments, 561.
—— and J. T. Bottomley on the illuminating powers of incandescent vacuum lamps with measured potentials and measured currents, 559.
Thomson (W.) on some phenomena which appear to be of the nature of chemico-magnetic action, 590.
Thorpe (Prof. T. E.) on the chemical action between solids, 580; on the action of zinç and magnesium on acidified solutions of ferric sulphate, 595; *on vapour density determinations, 597.
—— and Prof. A. W. Rücker on the calibration of mercurial thermometers by Bessel's method, 540.
Tidal observations at Madeira or other islands in the North Atlantic Ocean, the value of, 160.
Tiddeman (R. H.) on the erratic blocks of England, Wales, and Ireland, 204.
Tides, the stationary, in the English Channel and the North Sea, the phenomena of, fourth report on, 160.
Timor-laut, report on the natural history of, 197.
Topley (W.) on an international scale of colours for geological maps, 647.
*Torrens (Sir R.), results to be attained by applying to the transfer of land in this country the methods employed in the British Colonies, 760.
Tourmaline, the electric conductivity and dichroic absorption of, Prof. S. P. Thompson on, 531.
*Transfer of land, the results to be attained by applying to the, in this country the methods employed in the British Colonies, by Sir R. Torrens, 760.
*Transmission of power by electricity, J. N. Shoolbred on the, 779.
Tribe (A.), note on a new method of measuring certain chemical affinities, 592.
Tyndall (Prof. J.) on the arrestation of infusorial life by solar light, 450.

Underground temperature, fourteenth report on the rate of increase of, downwards in various localities of dry land and under water, 90.
Underground waters in the Jurassic, New Red Sandstone, and Permian formations of England, the circulation of the, and the quality and quantity of the water supplied to towns and districts from these formations, seventh report on, 309.
Upper Bagshot Sands of Hordwell Cliff, Hampshire, E. B. Tawney on the, 633.
Ussher (R. J.), report to the Committee for exploring the caves of the South of Ireland, 218.
Ussher (W. A. E.) on the Palæozoic rocks of North Devon and West Somerset, 629.

Vanadium solutions, the reducing action

of zinc and magnesium on, Prof. H. E. Roscoe on, 596.
Vapour density determinations, Prof. Dewar and A. Scott on some, 597.
*——, Prof. T. E. Thorpe on, 597.
Veley (V. H.) on the oxides of manganese, 582.
*Velocity function of a liquid due to the motion of cylinders and surfaces of revolution, A. G. Greenhill on the, 540.
Viking's ship, discovered at Sandefjord in Norway, 1880, by J. H. Stone, 689.
Village system and the tenure of land in the Dravidian villages of the Dekhan, notes on, by Sir W. Elliot, 758.
Vine (G. R.) on fossil polyzoa, 161.
Volcanic action, some observations on the causes of, by Prof. J. Prestwich, 610.
Volcanic rock, the intrusion of, and volcanic eruptions, Prof. Sollas on the connection between, 613.
Volta-electric inversion, Prof. S. P. Thompson on, 552.
Voltaic action, some preliminary experiments on, by J. Brown, 562.
Voltaic current, the effect of, on the elimination of sugar, W. H. Stone on, 724.
Vyle (S.) on a new form of lightning conductor, which can be easily tested, 780.

Wages and other sources of income, report on the present appropriation of, and how far it is consonant with the economic progress of the people of the United Kingdom, 272.
Wake (C. S.) on the Papuans and the Polynesians, 696.
Wales, Central, the glacial geology of, W. Keeping on, 648.
Waller (Rev. H.), some results of fifty years' exploration in Africa, 746.
Wanklyn (J. A.), note on the phosphates of lime and ammonia, 597.
Warington (R.) on alterations in the properties of the nitric ferment by cultivation, 593.
Watherston (E. J.) on societies of commercial geography, 748; on the progress of British commerce in a generation, 763.
Watts (Dr. M.) on the present state of our knowledge of spectrum analysis, 317.
*Wave apparatus for lecture purposes, to illustrate Fresnel's conception of polarised light, C. J. Woodward on a, 563.
Webster (Mrs. A.) on the manner in which rudimentary science should be taught, and how examinations should be held therein, in elementary schools, 148.
Weldon (W.) on the first two lines of Mendelejeff's table of atomic weights 580.
Westgarth (W.), a general banking law for the United Kingdom, 751; the silver question, and the double *versus* the single standard, 759.
Wethered (E.) on underground temperature, 90; on the formation of coal, 623.
Whipple (G. M.) on observations of atmospheric electricity at the Kew Observatory during 1880, 443; on a universal sunshine recorder stand, 540.
Whitaker (W.) on the circulation of underground waters, 309.
White light, a standard of, second report on an investigation for the purpose of fixing, 126.
Wigham (J. R.), *the advantages of ex-focal light in first-order dioptric lighthouses, 776; *on the value of quadriform gaslights for lighthouses in comparison with the electric light, 779.
Wilkinson (R.) on the manner in which rudimentary science should be taught, and how examinations should be held therein, in elementary schools, 148.
*Williams (H. S.) on the desirability of observing occultation of stars, of the first and other bright magnitudes, from places where they are to be seen near the horizon, 547.
Williams (W. C.) on the method of determining the specific refraction of solids from their solutions, 155.
Williamson (Prof. A. W.) on the manner in which rudimentary science should be taught, and how examinations should be held therein, in elementary schools, 148; on patent legislation, 222; on the present state of our knowledge of spectrum analysis, 317; Address by, to the Chemical Section, 568; on the present state of chemical nomenclature, 593.
Williamson (B.) on the calculation of sun-heat coefficients, 89.
Williamson (Prof. W. C.) on the tertiary flora of the North of Ireland, 152; preliminary remarks on the microscopic structure of coal, 625.
Wilson (E.) on a discovery of fossil fishes in the New Red Sandstone of Nottingham, 637; on the Rhætics of Nottinghamshire, 637.
Wilson (Rev. J. M.) and H. S. H. Shaw on a new integrating anemometer, 543.
Wind, the pressure of, upon a fixed plane surface, T. Hawksley on, 480.
Wood (H. T.) on patent legislation, 222.
Woods (Dr. T.) on drops and capillarity, 565.
*Woodward (C. J.) on a wave apparatus for lecture purposes, to illustrate Fresnel's conception of polarised light, 563.

Woolcombe (R. W.) on the causes and results of assumed cycloidal rotation in arterial red discs, 722.
*Wrightson (T.) and Prof. W. C. Roberts on the fluid density of certain metals, 582.
Wynn (Mrs. Williams) and Prof. T. McK. Hughes, the results of recent further excavations in the caves of Cefn, near St. Asaph, North Wales, 700.
Wynne (A. B.) on underground temperature, 90.

Yoshida (H.) and Prof. R. W. Atkinson on peppermint-camphor (menthol) and some of its derivatives, 585.

Zinc and magnesium, the action of, on acidified solutions of ferric sulphate, Prof. T. E. Thorpe on, 595.
—— the reducing action of, on vanadium solutions, Prof. H. E. Roscoe on, 596.
Zoological station at Naples, report of the Committee appointed to arrange for the occupation of a table at the, 178; reports to the Committee—by Allen Harker, 182; by F. G. Penrose, 183.
Zoological station, the Scottish, report of the Committee appointed to aid in the maintenance of, 177
Zulus, the physical characters and proportions of the, C. Roberts and G. W. Bloxam on, 702.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Life Members (since 1845), and all Annual Members who have not intermitted their Subscription, receive gratis all Reports published after the date of their Membership. Any other volume they require may be obtained on application at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., at the following prices, viz.—Reports for 1831 to 1874 (*of which more than* 15 *copies remain*), at 2*s*. 6*d*. per volume; after that date, at two-thirds of the Publication Price. A few sets, from 1831 to 1874 inclusive, may also be obtained at £10 per set.

Associates for the Meeting in 1881 may obtain the Volume for the Year at two-thirds of the Publication Price.

PROCEEDINGS OF THE FIRST AND SECOND MEETINGS, at York and Oxford, 1831 and 1832, *Published at* 13*s*. 6*d*.

CONTENTS:—Prof. Airy, on the Progress of Astronomy;—J. W. Lubbock, on the Tides;—Prof. Forbes, on the Present State of Meteorology;—Prof. Powell, on the Present State of the Science of Radiant Heat;—Prof. Cumming, on Thermo-Electricity;—Sir D. Brewster, on the Progress of Optics;—Rev. W. Whewell, on the Present State of Mineralogy;—Rev. W. D. Conybeare, on the Recent Progress and Present State of Geology;—Dr. Pritchard's Review of Philological and Physical Researches.

Together with Papers on Mathematics, Optics, Acoustics, Magnetism, Electricity, Chemistry, Meteorology, Geography, Geology, Zoology, Anatomy, Physiology, Botany, and the Arts; and an Exposition of the Objects and Plan of the Association, &c.

PROCEEDINGS OF THE THIRD MEETING, at Cambridge, 1833, *Published at* 12*s*. (Out of Print.)

CONTENTS:—Proceedings of the Meeting;—John Taylor, on Mineral Veins;—Dr. Lindley, on the Philosophy of Botany;—Dr. Henry, on the Physiology of the Nervous System;—P. Barlow, on the Strength of Materials;—S. H. Christie, on the Magnetism of the Earth;—Rev. J. Challis, on the Analytical Theory of Hydrostatics and Hydrodynamics;—G. Rennie, on Hydraulics as a Branch of Engineering, Part I.;—Rev. G. Peacock, on certain Branches of Analysis.

Together with Papers on Mathematics and Physics, Philosophical Instruments and Mechanical Arts, Natural History, Anatomy, Physiology, and History of Science.

PROCEEDINGS OF THE FOURTH MEETING, at Edinburgh, 1834, *Published at* 15*s.*

CONTENTS:—H. G. Rogers, on the Geology of North America;—Dr. C. Henry, on the Laws of Contagion;—Prof. Clark, on Animal Physiology;—Rev. L. Jenyns, on Zoology;—Rev. J. Challis, on Capillary Attraction;—Prof. Lloyd, on Physical Optics;—G. Rennie, on Hydraulics, Part II.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTH MEETING, at Dublin, 1835, *Published at* 13*s.* 6*d.*

CONTENTS:—Rev. W. Whewell, on the Recent Progress and Present Condition of the Mathematical Theories of Electricity, Magnetism, and Heat;—A. Quetelet, Aperçu de l'Etat actuel des Sciences Mathématiques chez les Belges;—Capt. E. Sabine, on the Phenomena of Terrestrial Magnetism.

Together with the Transactions of the Sections, Prof. Sir W. Hamilton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTH MEETING, at Bristol, 1836, *Published at* 12*s.*

CONTENTS:—Prof. Daubeny, on the Present State of our Knowledge with respect to Mineral and Thermal Waters;—Major E. Sabine, on the Direction and Intensity of the Terrestrial Magnetic Force in Scotland;—J. Richardson, on North American Zoology;—Rev. J. Challis, on the Mathematical Theory of Fluids;—J. T. Mackay, a Comparative View of the more remarkable Plants which characterize the neighbourhood of Dublin and Edinburgh, and the South-west of Scotland, &c.;—J. T. Mackay, Comparative Geographical Notices of the more remarkable Plants which characterize Scotland and Ireland;—Report of the London Sub-Committee of the Medical Section on the Motions and Sounds of the Heart;—Second Report of the Dublin Sub-Committee on the Motions and Sounds of the Heart;—Report of the Dublin Committee on the Pathology of the Brain and Nervous System;—J. W. Lubbock, Account of the Recent Discussions of Observations of the Tides;—Rev. B. Powell, on determining the Refractive Indices for the Standard Rays of the Solar Spectrum in various media;—Dr. Hodgkin, on the Communication between the Arteries and Absorbents;—Prof. Phillips, Report of Experiments on Subterranean Temperature;—Prof. Hamilton, on the Validity of a Method recently proposed by G. B. Jerrard, for Transforming and Resolving Equations of Elevated Degrees.

Together with the Transactions of the Sections, Prof. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTH MEETING, at Liverpool, 1837, *Published at* 16*s.* 6*d.*

CONTENTS:—Major E. Sabine, on the Variations of the Magnetic Intensity observed at different points of the Earth's Surface;—Rev. W. Taylor, on the various modes of Printing for the Use of the Blind;—J. W. Lubbock, on the Discussions of Observations of the Tides;—Prof. T. Thompson, on the Difference between the Composition of Cast Iron produced by the Cold and Hot Blast;—Rev. T. R. Robinson, on the Determination of the Constant of Nutation by the Greenwich Observations;—R. W. Fox, Experiments on the Electricity of Metallic Veins, and the Temperature of Mines;—Provisional Report of the Committee of the Medical Section of the British Association, appointed to investigate the Composition of Secretions, and the Organs producing them;—Dr. G. O. Rees, Report from the Committee for inquiring into the Analysis of the Glands, &c., of the Human Body;—Second Report of the London Sub-Committee of the British Association Medical Section, on the Motions and Sounds of the Heart;—Prof. Johnston, on the Present State of our Knowledge in regard to Dimorphous Bodies;—Lieut.-Col. Sykes, on the Statistics of the four Collectorates of Dukhun, under the British Government;—E. Hodgkinson, on the relative

Strength and other Mechanical Properties of Iron obtained from the Hot and Cold Blast;—W. Fairbairn, on the Strength and other Properties of Iron obtained from the Hot and Cold Blast;—Sir J. Robinson and J. S. Russell, Report of the Committee on Waves;—Note by Major Sabine, being an Appendix to his Report on the Variations of the Magnetic Intensity observed at different Points of the Earth's Surface; —J. Yates, on the Growth of Plants under Glass, and without any free communication with the outward Air, on the Plan of Mr. N. J. Ward, of London.

Together with the Transactions of the Sections, Prof. Traill's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTH MEETING, at Newcastle, 1838, *Published at* 15*s.*

CONTENTS:—Rev. W. Whewell, Account of a Level Line, measured from the Bristol Channel to the English Channel, by Mr. Bunt;—Report on the Discussions of Tides, prepared under the direction of the Rev. W. Whewell;—W. S. Harris, Account of the Progress and State of the Meteorological Observations at Plymouth;—Major E. Sabine, on the Magnetic Isoclinal and Isodynamic Lines in the British Islands; —Dr. Lardner, on the Determination of the Mean Numerical Values of Railway Constants;—R. Mallet, First Report upon Experiments upon the Action of Sea and River Water upon Cast and Wrought Iron;—R. Mallet, on the Action of a Heat of 212° Fahr., when long continued, on Inorganic and Organic Substances.

Together with the Transactions of the Sections, Mr. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINTH MEETING, at Birmingham, 1839, *Published at* 13*s.* 6*d.* (Out of Print.)

CONTENTS:—Rev. B. Powell, Report on the Present State of our Knowledge of Refractive Indices, for the Standard Rays of the Solar Spectrum in different media; Report on the Application of the Sum assigned for Tide Calculations to Rev. W. Whewell, in a letter from T. G. Bunt, Esq.;—H. L. Pattinson, on some Galvanic Experiments to determine the Existence or Non-Existence of Electrical Currents among Stratified Rocks, particularly those of the Mountain Limestone formation, constituting the Lead Measures of Alton Moor;—Sir D. Brewster, Reports respecting the Two Series of Hourly Meteorological Observations kept in Scotland;—Report on the subject of a series of Resolutions adopted by the British Association at their Meeting in August 1838, at Newcastle;—R. Owen, Report on British Fossil Reptiles; —E. Forbes, Report on the Distribution of the Pulmoniferous Mollusca in the British Isles;—W. S. Harris, Third Report on the Progress of the Hourly Meteorological Register at Plymouth Dockyard.

Together with the Transactions of the Sections, Rev. W. Vernon Harcourt's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TENTH MEETING, at Glasgow, 1840, *Published at* 15*s.* (Out of Print.)

CONTENTS:—Rev. B. Powell, Report on the Recent Progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science;—J. D. Forbes, Supplementary Report on Meteorology;—W. S. Harris, Report on Prof. Whewell's Anemometer, now in operation at Plymouth;—Report on 'The Motion and Sounds of the Heart,' by the London Committee of the British Association, for 1839-40;—Prof. Schönbein, an Account of Researches in Electro-Chemistry;—R. Mallet, Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron, and Steel;—R. W. Fox, Report on some Observations on Subterranean Temperature;—A. F. Osler, Report on the Observations recorded during the years 1837, 1838, 1839, and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham;—Sir D. Brewster, Report respecting the Two Series of Hourly Meteorological Observations kept at Inverness and Kingussie, from Nov. 1st, 1838, to Nov. 1st, 1839:—W. Thompson, Report on the Fauna of Ireland: Div. *Verte-*

brata;—C. J. B. Williams, M.D., Report of Experiments on the Physiology of the Lungs and Air-Tubes;—Rev. J. S. Henslow, Report of the Committee on the Preservation of Animal and Vegetable Substances.

Together with the Transactions of the Sections, Mr. Murchison and Major E. Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE ELEVENTH MEETING, at Plymouth, 1841, *Published at* 13*s*. 6*d*.

CONTENTS:—Rev. P. Kelland, on the Present State of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat;—G. L. Roupell, M.D., Report on Poisons;—T. G. Bunt, Report on Discussions of Bristol Tides, under the direction of the Rev. W. Whewell;—D. Ross, Report on the Discussions of Leith Tide Observations, under the direction of the Rev. W. Whewell;—W. S. Harris, upon the working of Whewell's Anemometer at Plymouth during the past year;—Report of a Committee appointed for the purpose of superintending the scientific 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 appointed 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;—Dr. D. Lardner, 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;—Dr. J. Richardson, 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;—Dr. Lyon Playfair, Abstract of Prof. Liebig's Report on Organic Chemistry applied to Physiology and Pathology;—R. Owen, Report on the British Fossil Mammalia, Part I.;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—L. Agassiz, Report on the Fossil Fishes of the Devonian System or Old Red Sandstone;—W. Fairbairn, Appendix to a Report on the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast;—D. Milne, Report of the Committee for Registering Shocks of Earthquakes in Great Britain;—Report of a Committee on the construction of a Constant Indicator for Steam-Engines, and for the determination of the Velocity of the Piston of the Self-acting Engine at different periods of the Stroke;—J. S. Russell, Report of a Committee on the Form of Ships;—Report of a Committee appointed 'to consider of the Rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis;'—Report of a Committee on the Vital Statistics of Large Towns in Scotland;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s.*

CONTENTS:—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at Various Temperatures, upon Cast Iron, Wrought Iron, and Steel;—Report of the Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations;—Report of the Committee appointed for Experiments on Steam-Engines;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland;—J. S. Russell, Notice of a Report of the Committee on the Form of Ships;—J. Blake, Report on the Physiological Action of Medicines;—Report of the Committee on Zoological Nomenclature;—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable;—Report of the Committee for conducting Experiments with Captive Balloons;—Prof. Wheatstone, Appendix to the Report;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs;—C. W. Peach, on the Habits of the Marine Testacea;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations;—R. Owen, Report on the British Fossil Mammalia, Part II.;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst;—W. Thompson, Report on the Fauna of Ireland: Div. *Invertebrata;*—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, the Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at* £1.

CONTENTS:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Economy of the *Araneidea* made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes;—Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines;—Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the 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, the Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12*s*.

CONTENTS :—Seventh Report of a Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lieut.-Col. Sabine, on some Points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15*s*.

CONTENTS :—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck, on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—Dr. J. Percy, Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s*.

CONTENTS :—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our Knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Aryan and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at* 9*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn, on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eight 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 Lieut.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at* 15*s.* (Out of Print.)

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840, to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at* 16*s*. 6*d*.

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water, and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Economical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850, to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at* 15*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Economy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s.* 6*d.*

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53;—James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Economy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations; —Dr. John P. Bell, Observations on the Character and Measurements of Degradation of the Yorkshire Coast;—First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration; —Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued);—Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54; —Second Report of the Committee on the Physical Character of the Moon's Surface; —W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s.*

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55;—Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18s.

CONTENTS :—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks ;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards ;—Dredging Report, Frith of Clyde, 1856 ;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856 ;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches ;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms ;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and neighbouring Seas, and the physical conditions affecting their development ;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America ;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores ;—Prof. Phillips, Report on Cleavage, and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena, Part 1 ;—Dr. T. Wright, on the Stratigraphical Distribution of the Oolitic Echinodermata ;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures ; —C. Atherton, on Mercantile Steam Transport Economy ;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon ;—Provisional Report on the Measurement of Ships for Tonnage ;—On Typical Forms of Minerals, Plants and Animals for Museums ;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards ;—R. Mallet, on Observations with the Seismometer ;—A. Cayley, on the Progress of Theoretical Dynamics ;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at* 15s.

CONTENTS :—A. Cayley, Report on the recent progress of Theoretical Dynamics ;—Sixteenth and Final Report of Committee on Experiments on the Growth and Vitality of Seeds ;—James Oldham, C.E., continuation of Report on Steam Navigation at Hull ;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-power of Steam Ships ;—Robert Were Fox, Report on the Temperature of some Deep Mimes in Cornwall ;—Dr. G. Plarr, de quelques Transformations de la Somme $\Sigma_0^{t^{-a}} \frac{a^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$ a étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $a^{t|+1}$ désignant le produit des facteurs $a\ (a+1)\ (a+2)$ &c.... $(a+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel ;—Charles Atherton, Suggestions for Statistical Inquiry into the Extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth ;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ ;—Dr. John P. Hodges, on Flax ;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain ;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57 ;—C. Vignoles, on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains ;—Prof. W. A. Miller, on Electro-Chemistry ;—John Simpson, Results of Thermometrical Observations made at the *Plover's* Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54 ;—Charles James Hargreave, on the Algebraic Couple ; and on the Equivalents of Indeterminate Expressions ;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings ;—Prof. James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn, on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, the Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at* 20*s*.

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857, 1858;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the Collapse of Glass Globes and Cylinders;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Michael Connel and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857;—Report of the Committee on Shipping Statistics;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857-58;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India;—George C. Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr. Vignoles' Paper 'On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;'—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories;—R. Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof. Owen's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at* 15*s*.

CONTENTS:—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to Cultivated Crops;—A. Thomson, of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahagow, Lanarkshire;—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Breaks for Railway Trains;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858-59;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858-59;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c., &c.;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—

G. C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren De La Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S.;—W. Fairbairn, The Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air:—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Professor H. J. Stephen Smith, Report on the Theory of Numbers, Part I.;—Report of the Committee on Steamship Performance;—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at* 15s.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1859–60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee;—Rev. J. Anderson, Report on the Excavations in Dura Den;—Prof. Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of the Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to prepare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders;—R. P. Greg, Catalogue of Meteorites and Fireballs, from A.D. 2 to A.D. 1860;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part II.;—Vice-Admiral Moorsom, on the Performance of Steam-vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel;—Rev. W. V. Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena;—Second Report of the Committee on Steamship Performance;—Interim Report on the Gauging of Water by Triangular Notches;—List of the British Marine Invertebrate Fauna.

Together with the Transactions of the Sections, Lord Wrottesley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIRST MEETING, at Manchester, September 1861, *Published at* £1.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors;—Dr. E. Smith, Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners, Part I.;—Charles Atherton, on Freight as affected by Differences in the Dynamic Properties of Steamships;—Warren De La Rue, Report on the Progress of Celestial Photography since the Aberdeen Meeting;—B. Stewart, on the Theory of Exchanges, and its recent extension;—Drs. E. Schunck, R. Angus Smith, and H. E. Roscoe, on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District;—Dr. J. Hunt, on Ethno-Climatology; or, the Acclimatization of Man;—Prof. J. Thomson, on Experiments on the Gauging of Water by Triangular Notches;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—Prof. H. Hennessy, Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound-signals during Fogs at Sea;—Dr. P. L. Sclater and F. von Hochstetter, Report on the Present State of our Knowledge of the Birds of the Genus *Apteryx* living in New Zealand;—J. G. Jeffreys, Report of the Results of Deep-sea Dredging in Zetland, with a Notice of several Species of Mollusca new to Science or to the British Isles;—Prof. J. Phillips, Contributions to a Report on the Physical Aspect of the Moon ;—W. R. Birt, Contribution to a Report on the Physical Aspect of the Moon;—Dr. Collingwood and Mr. Byerley, Preliminary Report of the Dredging Committee of the Mersey and Dee ;—Third Report of the Committee on Steamship Performance ;—J. G. Jeffreys, Preliminary Report on the Best Mode of preventing the Ravages of *Teredo* and other Animals in our Ships and Harbours ;—R. Mallet, Report on the Experiments made at Holyhead to ascertain the Transit-Velocity of Waves, analogous to Earthquake Waves, through the local Rock Formations ;—T. Dobson, on the Explosions in British Coal-Mines during the year 1859 ;—J. Oldham, Continuation of Report on Steam Navigation at Hull ;—Prof. G. Dickie, Brief Summary of a Report on the Flora of the North of Ireland ;—Prof. Owen, on the Psychical and Physical Characters of the Mincopies, or Natives of the Andaman Islands, and on the Relations thereby indicated to other Races of Mankind ;—Colonel Sykes, Report of the Balloon Committee ;—Major-General Sabine, Report on the Repetition of the Magnetic Survey of England ;—Interim Report of the Committee for Dredging on the North and East Coasts of Scotland ;—W. Fairbairn, on the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities ;—W. Fairbairn, Continuation of Report to determine the effect of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Girders ;—Report of the Committee on the Law of Patents ;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part III.

Together with the Transactions of the Sections, Mr. Fairbairn's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SECOND MEETING at Cambridge, October 1862, *Published at* £1.

CONTENTS :—James Glaisher, Report on Observations of Luminous Meteors, 1861–62 ;—G. B. Airy, on the Strains in the Interior of Beams ;—Archibald Smith and F. J. Evans, Report on the three Reports of the Liverpool Compass Committee ;—Report on Tidal Observations on the Humber ;—T. Aston, on Rifled Guns and Projectiles adapted for Attacking Armour-plate Defences ;—Extracts, relating to the Observatory at Kew, from a Report presented to the Portuguese Government, by Dr. J. A. de Souza ;—H. T. Mennell, Report on the Dredging of the Northumberland Coast and Dogger Bank ;—Dr. Cuthbert Collingwood, Report upon the best means of advancing Science through the agency of the Mercantile Marine ;—Messrs. Williamson, Wheatstone, Thomson, Miller, Matthiessen, and Jenkin, Provisional Report on Standards of Electrical Resistance ;—Preliminary Report of the Committee for investigating the Chemical and Mineralogical Composition of the Granites of Donegal ;—Prof. H. Hennessy, on the Vertical Movements of the Atmosphere considered in connection with Storms and Changes of Weather ;—Report of Committee on the application of Gauss's General Theory of Terrestrial Magnetism to the Magnetic Variations ;—Fleeming Jenkin, on Thermo-electric Currents in Circuits of one Metal ;—W. Fairbairn, on the Mechanical Properties of Iron Projectiles at High Velocities ;—A. Cayley, Report on the Progress of the Solution of certain Special Problems of Dynamics ;—Prof. G. G. Stokes, Report on Double Refraction ;—Fourth Report of the Committee on Steamship Performance ;—G. J. Symons, on the Fall of Rain in the British Isles in 1860 and 1861 ;—J. Ball, on Thermometric Observations in the Alps ;—J. G. Jeffreys, Report of the Committee for Dredging on the North and East Coasts of Scotland ;—Report of the Committee on Technical and Scientific Evidence in Courts of Law ;—James Glaisher, Account of Eight Balloon Ascents in 1862 ;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part IV.

Together with the Transactions of the Sections, the Rev. Prof. R. Willis's Address and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-THIRD MEETING, at Newcastle-upon-Tyne, August and September 1863, *Published at* £1 5*s*.

CONTENTS :—Report of the Committee on the Application of Gun-cotton to Warlike Purposes ;—A. Matthiessen, Report on the Chemical Nature of Alloys ;—Report of the Committee on the Chemical and Mineralogical Constitution of the Granites of Donegal, and on the Rocks associated with them ;—J. G. Jeffreys, Report of the Committee appointed for exploring the Coasts of Shetland by means of the Dredge ;—

G. D. Gibb, Report on the Physiological Effects of the Bromide of Ammonium;—C. K. Aken, on the Transmutation of Spectral Rays, Part I.;—Dr. Robinson, Report of the Committee on Fog Signals;—Report of the Committee on Standards of Electrical Resistance;—E. Smith, Abstract of Report by the Indian Government on the Foods used by the Free and Jail Populations in India;—A. Gages, Synthetical Researches on the Formation of Minerals, &c.;—R. Mallet, Preliminary Report on the Experimental Determination of the Temperatures of Volcanic Foci, and of the Temperature, State of Saturation, and Velocity of the issuing Gases and Vapours;—Report of the Committee on Observations of Luminous Meteors;—Fifth Report of the Committee on Steamship Performance;—G. J. Allman, Report on the Present State of our Knowledge of the Reproductive System in the Hydroida;—J. Glaisher, Account of Five Balloon Ascents made in 1863;—P. P. Carpenter, Supplementary Report on the Present State of our Knowledge with regard to the Mollusca of the West Coast of North America;—Prof. Airy, Report on Steam Boiler Explosions;—C. W. Siemens, Observations on the Electrical Resistance and Electrification of some Insulating Materials under Pressures up to 300 Atmospheres;—C. M. Palmer, on the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear, and Tees;—Messrs. Richardson, Stevenson, and Clapham, on the Chemical Manufactures of the Northern Districts;—Messrs. Sopwith and Richardson, on the Local Manufacture of Lead, Copper, Zinc, Antimony, &c.;—Messrs. Daglish and Forster, on the Magnesian Limestone of Durham;—I. L. Bell, on the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field;—T. Spencer, on the Manufacture of Steel in the Northern District;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part V.

Together with the Transactions of the Sections, Sir William Armstrong's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FOURTH MEETING, at Bath, September 1864, *Published at* 18*s.*

CONTENTS:—Report of the Committee for Observations of Luminous Meteors;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—T. S. Cobbold, Report of Experiments respecting the Development and Migration of the Entozoa;—B. W. Richardson, Report on the Physiological Action of Nitrite of Amyl;—J. Oldham, Report of the Committee on Tidal Observations;—G. S. Brady, Report on Deep-sea Dredging on the Coasts of Northumberland and Durham in 1864;—J. Glaisher, Account of Nine Balloon Ascents made in 1863 and 1864;—J. G. Jeffreys, Further Report on Shetland Dredgings;—Report of the Committee on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report of the Committee on Standards of Electrical Resistance;—G. J. Symons, on the Fall of Rain in the British Isles in 1862 and 1863;—W. Fairbairn, Preliminary Investigation of the Mechanical Properties of the proposed Atlantic Cable.

Together with the Transactions of the Sections, Sir Charles Lyell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIFTH MEETING, at Birmingham, September 1865, *Published at* £1 5*s.*

CONTENTS:—J. G. Jeffreys, Report on Dredging among the Channel Isles;—F. Buckland, Report on the Cultivation of Oysters by Natural and Artificial Methods;—Report of the Committee for exploring Kent's Cavern;—Report of the Committee on Zoological Nomenclature;—Report on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Interim Report on the Resistance of Water to Floating and Immersed Bodies;—Report on Observations of Luminous Meteors;—Report on Dredging on the Coast of Aberdeenshire;—J. Glaisher, Account of Three Balloon Ascents;—Interim Report on the Transmission of Sound under Water;—G. J. Symons, on the Rainfall of the British Isles;—W. Fairbairn, on the Strength of Materials considered in relation to the Construction of Iron Ships;—Report of the Gun-Cotton Committee;—A. F. Osler, on the Horary and Diurnal Variations in the Direction and Motion of the Air at Wrottesley, Liverpool, and

Birmingham;—B. W. Richardson, Second Report on the Physiological Action of certain of the Amyl Compounds; – Report on further Researches in the Lingula-flags of South Wales;—Report of the Lunar Committee for Mapping the Surface of the Moon;—Report on Standards of Electrical Resistance;—Report of the Committee appointed to communicate with the Russian Government respecting Magnetical Observations at Tiflis;—Appendix to Report on the Distribution of the Vertebrate Remains from the North Staffordshire Coal-field;—H. Woodward, First Report on the Structure and Classification of the Fossil Crustacea;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part VI.;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science; —A. G. Findlay, on the Bed of the Ocean;—Prof. A. W. Williamson, on the Composition of Gases evolved by the Bath Spring called King's Bath.

Together with the Transactions of the Sections, Prof. Phillips's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SIXTH MEETING, at Nottingham, August 1866, *Published at* £1 4*s*.

CONTENTS:—Second Report on Kent's Cavern, Devonshire;—A. Matthiessen, Preliminary Report on the Chemical Nature of Cast Iron;—Report on Observations of Luminous Meteors;—W. S. Mitchell, Report on the Alum Bay Leaf-bed;—Report on the Resistance of Water to Floating and Immersed Bodies;—Dr. Norris, Report on Muscular Irritability;—Dr. Richardson, Report on the Physiological Action of certain compounds of Amyl and Ethyl;—H. Woodward, Second Report on the Structure and Classification of the Fossil Crustacea;—Second Report on the 'Menevian Group,' and the other Formations at St. David's, Pembrokeshire; —J. G. Jeffreys, Report on Dredging among the Hebrides;—Rev. A. M. Norman, Report on the Coasts of the Hebrides, Part II.;—J. Alder, Notices of some Invertebrata, in connexion with Mr. Jeffreys's Report;—G. S. Brady, Report on the *Ostracoda* dredged amongst the Hebrides;—Report on Dredging in the Moray Firth; —Report on the Transmission of Sound-Signals under Water;—Report of the Lunar Committee;—Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science;—J. Glaisher, Account of Three Balloon Ascents;—Report on the Extinct Birds of the Mascarene Islands;—Report on the Penetration of Iron-clad Ships by Steel Shot;—J. A. Wanklyn, Report on Isomerism among the Alcohols;—Report on Scientific Evidence in Courts of Law;—A. L. Adams, Second Report on Maltese Fossiliferous Caves, &c.

Together with the Transactions of the Sections, Mr. Grove's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SEVENTH MEETING, at Dundee, September 1867, *Published at* £1 6*s*.

CONTENTS:—Report of the Committee for Mapping the Surface of the Moon;—Third Report on Kent's Cavern, Devonshire;—On the present State of the Manufacture of Iron in Great Britain;—Third Report on the Structure and Classification of the Fossil Crustacea;—Report on the Physiological Action of the Methyl Compounds;—Preliminary Report on the Exploration of the Plant-Beds of North Greenland;—Report of the Steamship Performance Committee;—On the Meteorology of Port Louis, in the Island of Mauritius;—On the Construction and Works of the Highland Railway;—Experimental Researches on the Mechanical Properties of Steel;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Supplement to a Report on the Extinct Didine Birds of the Mascarene Islands;—Report on Observations of Luminous Meteors;—Fourth Report on Dredging among the Shetland Isles;—Preliminary Report on the Crustacea, &c., procured by the Shetland Dredging Committee in 1867;—Report on the Foraminifera obtained in the Shetland Seas;—Second Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-EIGHTH MEETING, at Norwich, August 1868, *Published at £1 5s.*

CONTENTS:—Report of the Lunar Committee;—Fourth Report on Kent's Cavern, Devonshire;—On Puddling Iron;—Fourth Report on the Structure and Classification of the Fossil Crustacea;—Report on British Fossil Corals;—Report on Spectroscopic Investigations of Animal Substances;—Report of Steamship Performance Committee;—Spectrum Analysis of the Heavenly Bodies;—On Stellar Spectrometry;—Report on the Physiological Action of the Methyl and allied Compounds;—Report on the Action of Mercury on the Biliary Secretion;—Last Report on Dredging among the Shetland Isles;—Reports on the Crustacea, &c., and on the Annelida and Foraminifera from the Shetland Dredgings;—Report on the Chemical Nature of Cast Iron, Part I.;—Interim Report on the Safety of Merchant Ships and their Passengers;—Report on Observations of Luminous Meteors;—Preliminary Report on Mineral Veins containing Organic Remains;—Report on the Desirability of Explorations between India and China;—Report of Rainfall Committee;—Report on Synthetical Researches on Organic Acids;—Report on Uniformity of Weights and Measures;—Report of the Committee on Tidal Observations;—Report of the Committee on Underground Temperature;—Changes of the Moon's Surface;—Report on Polyatomic Cyanides.

Together with the Transactions of the Sections, Dr. Hooker's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-NINTH MEETING, at Exeter, August 1869, *Published at £1 2s.*

CONTENTS:—Report on the Plant-beds of North Greenland;—Report on the existing knowledge on the Stability, Propulsion, and Sea-going qualities of Ships;—Report on Steam-boiler Explosions;—Preliminary Report on the Determination of the Gases existing in Solution in Well-waters;—The Pressure of Taxation on Real Property;—On the Chemical Reactions of Light discovered by Prof. Tyndall;—On Fossils obtained at Kiltorkan Quarry, co. Kilkenny;—Report of the Lunar Committee;—Report on the Chemical Nature of Cast Iron;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Report on the Practicability of establishing a 'Close Time' for the Protection of Indigenous Animals;—Experimental Researches on the Mechanical Properties of Steel;—Second Report on British Fossil Corals;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals for Photographing;—Report on the Rate of Increase of Underground Temperature;—Fifth Report on Kent's Cavern, Devonshire;—Report on the Connexion between Chemical Constitution and Physiological Action;—On Emission, Absorption, and Reflection of Obscure Heat;—Report on Observations of Luminous Meteors;—Report on Uniformity of Weights and Measures;—Report on the Treatment and Utilization of Sewage;—Supplement to Second Report of the Steamship-Performance Committee;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Mineral Veins in Carboniferous Limestone and their Organic Contents;—Notes on the Foraminifera of Mineral Veins and the Adjacent Strata;—Report of the Rainfall Committee;—Interim Report on the Laws of the Flow and Action of Water containing Solid Matter in Suspension;—Interim Report on Agricultural Machinery;—Report on the Physiological Action of Methyl and Allied Series;—On the Influence of Form considered in Relation to the Strength of Railway-axles and other portions of Machinery subjected to Rapid Alterations of Strain;—On the Penetration of Armour-plates with Long Shells of Large Capacity fired obliquely;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, Prof. Stokes's Address, and Recommendation of th Association and its Committees.

PROCEEDINGS OF THE FORTIETH MEETING, at Liverpool, September 1870, *Published at* 18*s.*

CONTENTS :—Report on Steam-boiler Explosions ;—Report of the Committee on the Hæmatite Iron-ores of Great Britain and Ireland ;—Report on the Sedimentary Deposits of the River Onny ;—Report on the Chemical Nature of Cast Iron ;—Report on the practicability of establishing a 'Close Time' for the protection of Indigenous Animals ;—Report on Standards of Electrical Resistance ;—Sixth Report on Kent's Cavern ;—Third Report on Underground Temperature ;—Second Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals ;—Second Report on the Stability, Propulsion, and Sea-going Qualities of Ships ;—Report on Earthquakes in Scotland ;—Report on the Treatment and Utilization of Sewage ;—Report on Observations of Luminous Meteors, 1869–70 ;—Report on Recent Progress in Elliptic and Hyperelliptic Functions ;—Report on Tidal Observations ;—On a new Steam-power Meter ;—Report on the Action of the Methyl and Allied Series ;—Report of the Rainfall Committee ;—Report on the Heat generated in the Blood in the Process of Arterialization ;—Report on the best means of providing for Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. Huxley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIRST MEETING, at Edinburgh, August 1871, *Published at* 16*s.*

CONTENTS :—Seventh Report on Kent's Cavern ;—Fourth Report on Underground Temperature ;—Report on Observations of Luminous Meteors, 1870–71 ;—Fifth Report on the Structure and Classification of the Fossil Crustacea ;—Report of the Committee appointed for the purpose of urging on Her Majesty's Government the expediency of arranging and tabulating the results of the approaching Census in the three several parts of the United Kingdom in such a manner as to admit of ready and effective comparison ;—Report of the Committee appointed for the purpose of Superintending the Publication of Abstracts of Chemical Papers ;—Report of the Committee for discussing Observations of Lunar Objects suspected of change ;—Second Provisional Report on the Thermal Conductivity of Metals ;—Report on the Rainfall of the British Isles ;—Third Report on the British Fossil Corals ;—Report on the Heat generated in the Blood during the Process of Arterialization ;—Report of the Committee appointed to consider the subject of Physiological Experimentation ;—Report on the Physiological Action of Organic Chemical Compounds ;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals ;—Second Report on Steam-Boiler Explosions ;—Report on the Treatment and Utilization of Sewage ;—Report on promoting the Foundation of Zoological Stations in different parts of the World ;—Preliminary Report on the Thermal Equivalents of the Oxides of Chlorine ;- Report on the practicability of establishing a 'Close Time' for the protection of Indigenous Animals ;—Report on Earthquakes in Scotland ;—Report on the best means of providing for a Uniformity of Weights and Measures ;—Report on Tidal Observations.

Together with the Transactions of the Sections, Sir William Thomson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SECOND MEETING, at Brighton, August 1872, *Published at* £1 4*s.*

CONTENTS :—Report on the Gaussian Constants for the Year 1829 ;—Second Supplementary Report on the Extinct Birds of the Mascarene Islands ;—Report of the Committee for Superintending the Monthly Reports of the Progress of Chemistry ;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures ;—Eighth Report on Kent's Cavern ;—Report on promoting the Foundation of Zoological Stations in different parts of the World ;—Fourth Report on the Fauna of South Devon ;—Preliminary Report of the Committee appointed to Construct and Print Catalogues of Spectral Rays arranged upon a Scale of Wave-numbers ;—Third Report on Steam-Boiler Explosions ;—Report on Observations of

Luminous Meteors, 1871-72;—Experiments on the Surface-friction experienced by a Plane moving through Water;—Report of the Committee on the Antagonism between the Action of Active Substances;—Fifth Report on Underground Temperature;—Preliminary Report of the Committee on Siemens's Electrical-Resistance Pyrometer:—Fourth Report on the Treatment and Utilization of Sewage;—Interim Report of the Committee on Instruments for Measuring the Speed of Ships and Currents;—Report on the Rainfall of the British Isles;—Report of the Committee on a Geographical Exploration of the Country of Moab;—Sur l'élimination des Fonctions Arbitraires;—Report on the Discovery of Fossils in certain remote parts of the North-western Highlands;—Report of the Committee on Earthquakes in Scotland;—Fourth Report on Carboniferous-Limestone Corals;—Report of the Committee to consider the mode in which new Inventions and Claims for Reward in respect of adopted Inventions are examined and dealt with by the different Departments of Government;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Report on the Mollusca of Europe;—Report of the Committee for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report on the practicability of establishing a 'Close Time' for the preservation of Indigenous Animals;—Sixth Report on the Structure and Classification of Fossil Crustacea;—Report of the Committee appointed to organize an Expedition for observing the Solar Eclipse of Dec. 12, 1871;—Preliminary Report of a Committee on Terato-embryological Inquiries;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On the Brighton Waterworks;—On Amsler's Planimeter.

Together with the Transactions of the Sections, Dr. Carpenter's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-THIRD MEETING, at Bradford, September 1873, *Published at £1 5s.*

CONTENTS:—Report of the Committee on Mathematical Tables;—Observations on the Application of Machinery to the Cutting of Coal in Mines;—Concluding Report on the Maltese Fossil Elephants;—Report of the Committee for ascertaining the Existence in different parts of the United Kingdom of any Erratic Blocks or Boulders;—Fourth Report on Earthquakes in Scotland;—Ninth Report on Kent's Cavern;—On the Flint and Chert Implements found in Kent's Cavern;—Report of the Committee for Investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report of Inquiry into the Method of making Gold-assays;—Fifth Report on the Selection and Nomenclature of Dynamical and Electrical Units;—Report of the Committee on the Labyrinthodonts of the Coal-measures;—Report of the Committee appointed to construct and print Catalogues of Spectral Rays;—Report of the Committee appointed to explore the Settle Caves;—Sixth Report on Underground Temperature;—Report on the Rainfall of the British Isles;—Seventh Report on Researches in Fossil Crustacea;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on the desirability of establishing a 'Close Time' for the preservation of Indigenous Animals;—Report on Luminous Meteors;—On the Visibility of the Dark Side of Venus;—Report of the Committee for the Foundation of Zoological Stations in different parts of the World;—Second Report of the Committee for collecting Fossils from North-western Scotland;—Fifth Report on the Treatment and Utilization of Sewage;—Report of the Committee on Monthly Reports of the Progress of Chemistry;—On the Bradford Waterworks;—Report on the possibility of Improving the Methods of Instruction in Elementary Geometry;—Interim Report of the Committee on Instruments for Measuring the Speed of Ships, &c.;—Report of the Committee for Determinating High Temperatures by means of the Refrangibility of Light evolved by Fluid or Solid Substances;—On a periodicity of Cyclones and Rainfall in connexion with Sun-spot Periodicity;—Fifth Report on the Structure of Carboniferous-Limestone Corals;—Report of the Committee on preparing and publishing brief forms of Instructions for Travellers, Ethnologists, &c.;—Preliminary Note from the Committee on the Influence of Forests on the Rainfall;—Report of the Sub-Wealden Exploration Committee;—Report of the Committee on Machinery for obtaining a Record of the Roughness of the Sea and Measurement of Waves near shore;—Report on Science Lectures and Organization;—Second Report on Science Lectures and Organization.

Together with the Transactions of the Sections, Prof. A. W. Williamson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FOURTH MEETING, at Belfast, August 1874, *Published at* £1 5*s*.

CONTENTS:—Tenth Report on Kent's Cavern;—Report for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Second Report of the Sub-Wealden Exploration Committee;—On the Recent Progress and Present State of Systematic Botany;—Report of the Committee for investigating the Nature of Intestinal Secretion;—Report of the Committee on the Teaching of Physics in Schools;—Preliminary Report for investigating Isomeric Cresols and their Derivatives;—Third Report of the Committee for collecting Fossils from localities in North-western Scotland;—Report on the Rainfall of the British Isles;—On the Belfast Harbour;—Report of Inquiry into the Method of making Gold-assays;—Report of a Committee on Experiments to determine the Thermal Conductivities of certain Rocks;—Second Report on the Exploration of the Settle Caves;—On the Industrial uses of the Upper Bann River;—Report of the Committee on the Structure and Classification of the Labyrinthodont;—Second Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c.;—Sixth Report on the Treatment and Utilization of Sewage;—Report on the Anthropological Notes and Queries for the use of Travellers;—On Cyclone and Rainfall Periodicities;—Fifth Report on Earthquakes in Scotland;—Report of the Committee appointed to prepare and print Tables of Wave-numbers;—Report of the Committee for testing the new Pyrometer of Mr. Siemens;—Report to the Lords Commissioners of the Admiralty on Experiments for the Determination of the Frictional Resistance of Water on a Surface, &c.;—Second Report for the Selection and Nomenclature of Dynamical and Electrical Units;—On Instruments for measuring the Speed of Ships;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee to inquire into the economic effects of Combinations of Labourers and Capitalists;—Preliminary Report on Dredging on the Coasts of Durham and North Yorkshire;—Report on Luminous Meteors;—Report on the best means of providing for a Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. John Tyndall's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIFTH MEETING, at Bristol, August 1875, *Published at* £1 5*s*.

CONTENTS:—Eleventh Report on Kent's Cavern;—Seventh Report on Underground Temperature;—Report on the Zoological Station at Naples;—Report of a Committee appointed to inquire into the Methods employed in the Estimation of Potash and Phosphoric Acid in Commercial Products;—Report on the present state of our Knowledge of the Crustacea;—Second Report on the Thermal Conductivities of certain Rocks;—Preliminary Report of the Committee for extending the Observations on the Specific Volumes of Liquids;—Sixth Report on Earthquakes in Scotland;—Seventh Report on the Treatment and Utilization of Sewage;—Report of the Committee for furthering the Palestine Explorations;—Third Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c.;—Report of the Rainfall Committee;—Report of the Committee for investigating Isomeric Cresols and their Derivatives;—Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—On the Steering of Screw-Steamers;—Second Report of the Committee on Combinations of Capital and Labour;—Report on the Method of making Gold-assays;—Eighth Report on Underground Temperature;—Tides in the River Mersey;—Sixth Report of the Committee on the Structure of Carboniferous Corals;—Report of the Committee appointed to explore the Settle Caves;—On the River Avon (Bristol), its Drainage-Area, &c.;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee appointed to superintend the Publication of the Monthly Reports of the Progress of Chemistry;—Report on Dredging off the Coasts of Durham and North Yorkshire in 1874;—Report on Luminous Meteors;—On the Analytical Forms called Trees;—Report of the Committee on Mathematical

Tables;—Report of the Committee on Mathematical Notation and Printing;—Second Report of the Committee for investigating Intestinal Secretion;—Third Report of the Sub-Wealden Exploration Committee.

Together with the Transactions of the Sections, Sir John Hawkshaw's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SIXTH MEETING, at Glasgow, September 1876, *Published at £1 5s.*

CONTENTS:—Twelfth Report on Kent's Cavern;—Report on Improving the Methods of Instruction in Elementary Geometry;—Results of a Comparison of the British-Association Units of Electrical Resistance;—Third Report on the Thermal Conductivities of certain Rocks;—Report of the Committee on the practicability of adopting a Common Measure of Value in the Assessment of Direct Taxation;—Report of the Committee for testing experimentally Ohm's Law;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee on the Effect of Propellers on the Steering of Vessels;—On the Investigation of the Steering Qualities of Ships;—Seventh Report on Earthquakes in Scotland;—Report on the present state of our Knowledge of the Crustacea;—Second Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—Fourth Report of the Committee on the Erratic Blocks of England and Wales, &c.;—Fourth Report of the Committee on the Exploration of the Settle Caves (Victoria Cave);—Report on Observations of Luminous Meteors, 1875–76;—Report on the Rainfall of the British Isles, 1875–76;—Ninth Report on Underground Temperature;—Nitrous Oxide in the Gaseous and Liquid States;—Eighth Report on the Treatment and Utilization of Sewage;—Improved Investigations on the Flow of Water through Orifices, with Objections to the modes of treatment commonly adopted;—Report of the Anthropometric Committee;—On Cyclone and Rainfall Periodicities in connexion with the Sun-spot Periodicity;—Report of the Committee for determining the Mechanical Equivalent of Heat;—Report of the Committee on Tidal Observations;—Third Report of the Committee on the Conditions of Intestinal Secretion and Movement;—Report of the Committee for collecting and suggesting subjects for Chemical Research.

Together with the Transactions of the Sections, Dr. T. Andrews's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SEVENTH MEETING, at Plymouth, August 1877, *Published at £1 4s.*

CONTENTS:—Thirteenth Report on Kent's Cavern;—Second and Third Reports on the Methods employed in the estimation of Potash and Phosphoric Acid in Commercial Products;—Report on the present state of our Knowledge of the Crustacea (Part III.);—Third Report on the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—Fifth Report on the Erratic Blocks of England, Wales, and Ireland;—Fourth Report on the Thermal Conductivities of certain Rocks;—Report on Observations of Luminous Meteors, 1876–77;—Tenth Report on Underground Temperature;—Report on the Effect of Propellers on the Steering of Vessels;—Report on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report on some Double Compounds of Nickel and Cobalt;—Fifth Report on the Exploration of the Settle Caves (Victoria Cave);—Report on the Datum Level of the Ordnance Survey of Great Britain;—Report on the Zoological Station at Naples;—Report of the Anthropometric Committee;—Report on the Conditions under which Liquid Carbonic Acid exists in Rocks and Minerals.

Together with the Transactions of the Sections, Prof. Allen Thomson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-EIGHTH MEETING, at Dublin, August 1878, *Published at £1 4s.*

CONTENTS :—Catalogue of the Oscillation-Frequencies of Solar Rays;—Report on Mr. Babbage's Analytical Machine;—Third Report of the Committee for determining the Mechanical Equivalent of Heat;—Report of the Committee for arranging for the taking of certain Observations in India, and Observations on Atmospheric Electricity at Madeira;—Report on the commencement of Secular Experiments upon the Elasticity of Wires;—Report on the Chemistry of some of the lesser-known Alkaloids, especially Veratria and Bebeerine;—Report on the best means for the Development of Light from Coal-Gas;—Fourteenth Report on Kent's Cavern;—Report on the Fossils in the North-west Highlands of Scotland;—Fifth Report on the Thermal Conductivities of certain Rocks;—Report on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report on the occupation of a Table at the Zoological Station at Naples;—Report of the Anthropometric Committee;—Report on Patent Legislation;—Report on the Use of Steel for Structural Purposes;—Report on the Geographical Distribution of the Chiroptera;—Recent Improvements in the Port of Dublin;—Report on Mathematical Tables;—Eleventh Report on Underground Temperature;—Report on the Exploration of the Fermanagh Caves;—Sixth Report on the Erratic Blocks of England, Wales, and Ireland;—Report on the present state of our Knowledge of the Crustacea (Part IV.);—Report on two Caves in the neighbourhood of Tenby;—Report on the Stationary Tides in the English Channel and in the North Sea, &c.;—Second Report on the Datum-level of the Ordnance Survey of Great Britain;—Report on Instruments for measuring the Speed of Ships;—Report of Investigations into a Common Measure of Value in Direct Taxation;—Report on Sunspots and Rainfall; —Report on Observations of Luminous Meteors;—Sixth Report on the Exploration of the Settle Caves (Victoria Cave);—Report on the Kentish Boring Exploration;—Fourth Report on the Circulation of Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations, with an Appendix on the Filtration of Water through Triassic Sandstone;—Report on the Effect of Propellers on the Steering of Vessels.

Together with the Transactions of the Sections, Mr. Spottiswoode's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-NINTH MEETING, at Sheffield, August 1879, *Published at £1 4s.*

CONTENTS:—Report on the commencement of Secular Experiments upon the Elasticity of Wires;—Fourth Report of the Committee for determining the Mechanical Equivalent of Heat;—Report of the Committee for endeavouring to procure reports on the Progress of the Chief Branches of Mathematics and Physics;—Twelfth Report on Underground Temperature;—Report on Mathematical Tables;—Sixth Report on the Thermal Conductivities of certain Rocks;—Report on Observations of Atmospheric Electricity at Madeira;—Report on the Calculation of Tables of the Fundamental Invariants of Algebraic Forms;—Report on the Calculation of Sun-Heat Coefficients;—Second Report on the Stationary Tides in the English Channel and in the North Sea, &c.;—Report on Observations of Luminous Meteors;—Report on the question of Improvements in Astronomical Clocks;—Report of the Committee for improving an Instrument for detecting the presence of Fire-damp in Mines;—Report on the Chemistry of some of the lesser-known Alkaloids, especially Veratria and Bebeerine;—Seventh Report on the Erratic Blocks of England, Wales, and Ireland;—Fifteenth Report on Kent's Cavern;—Report on certain Caves in Borneo;—Fifth Report on the Circulation of Underground Waters in the Jurassic, Red Sandstone, and Permian Formations of England;—Report on the Tertiary (Miocene) Flora, &c., of the Basalt of the North of Ireland;—Report on the possibility of Establishing a 'Close Time' for the Protection of Indigenous Animals;—Report on the Marine Zoology of Devon and Cornwall;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on Excavations at Portstewart and elsewhere in the North of Ireland;—Report of the Anthropometric Committee;—Report on the Investigation of the Natural History of Socotra;—Report on Instruments for measuring the Speed of Ships;—Third Report on the Datum-level of the Ordnance Survey of Great Britain;—Second Report on Patent Legislation;—On Self-acting Intermittent Siphons and the conditions which determine the commencement of their Action;—On some further Evidence as to the Range of the Palæozoic Rocks beneath the South-east of England;—Hydrography, Past and Present.

Together with the Transactions of the Sections, Prof. Allman's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTIETH MEETING, at Swansea, August and September 1880, *Published at* £1 4s.

CONTENTS:—Report on the Measurement of the Lunar Disturbance of Gravity;—Thirteenth Report on Underground Temperature;—Report of the Committee for devising and constructing an improved form of High Insulation Key for Electrometer Work;—Report on Mathematical Tables;—Report on the Calculation of Tables of the Fundamental Invariants of Algebraic Forms;—Report on Observations of Luminous Meteors;—Reports on the question of Improvements in Astronomical Clocks;—Report on the commencement of Secular Experiments on the Elasticity of Wires;—Sixteenth and concluding Report on Kent's Cavern;—Report on the mode of reproduction of certain species of Ichthyosaurus from the Lias of England and Würtemburg;—Report on the Carboniferous Polyzoa;—Report on the 'Geological Record';—Sixth Report on the Circulation of the Underground Waters in the Permian, New Red Sandstone, and Jurassic Formations of England, and the Quantity and Character of the Water supplied to towns and districts from these formations;—Second Report on the Tertiary (Miocene) Flora, &c., of the Basalt of the North of Ireland;—Eighth Report on the Erratic Blocks of England, Wales, and Ireland;—Report on an Investigation for the purpose of fixing a Standard of White Light;—Report of the Anthropometric Committee;—Report on the Influence of Bodily Exercise on the Elimination of Nitrogen;—Second Report on the Marine Zoology of South Devon;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on accessions to our knowledge of the Chiroptera during the past two years (1878–80);—Preliminary Report on the accurate measurement of the specific inductive capacity of a good Sprengel Vacuum, and the specific resistance of gases at different pressures;—Comparison of Curves of the Declination Magnetographs at Kew, Stonyhurst, Coimbra, Lisbon, Vienna, and St. Petersburg;—First Report on the Caves of the South of Ireland;—Report on the Investigation of the Natural History of Socotra;—Report on the German and other systems of teaching the Deaf to speak;—Report of the Committee for considering whether it is important that H.M. Inspectors of Elementary Schools should be appointed with reference to their ability for examining in the scientific specific subjects of the Code in addition to other matters;—On the Anthracite Coal and Coalfield of South Wales;—Report on the present state of our knowledge of Crustacea (Part V.);—Report on the best means for the Development of Light from Coal-gas of different qualities (Part II.);—Report on Palæontological and Zoological Researches in Mexico;—Report on the possibility of establishing a 'Close Time' for Indigenous Animals;—Report on the present state of our knowledge of Spectrum Analysis;—Report on Patent Legislation;—Preliminary Report on the present Appropriation of Wages, &c.;—Report on the present state of knowledge of the application of Quadratures and Interpolation to Actual Data;—The French Deep-sea Exploration in the Bay of Biscay;—Third Report on the Stationary Tides in the English Channel and in the North Sea, &c.;—List of Works on the Geology, Mineralogy, and Palæontology of Wales (to the end of 1873);—On the recent Revival in Trade.

Together with the Transactions of the Sections, Dr. A. C. Ramsay's Address, and Recommendations of the Association and its Committees.

BRITISH ASSOCIATION

FOR

THE ADVANCEMENT OF SCIENCE.

LIST

OF

OFFICERS, COUNCIL, AND MEMBERS,

CORRECTED TO JANUARY, 1882.

OFFICERS AND COUNCIL, 1881-82.

PRESIDENT.

SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D. F.R.S., Pres. L.S., F.G.S.

VICE-PRESIDENTS.

His Grace the ARCHBISHOP OF YORK, D.D., F.R.S.
The Right Hon. the LORD MAYOR OF YORK.
The Right. Hon. Lord HOUGHTON, M.A., D.C.L., F.R.S., F.R.G.S.
The Ven. Archdeacon CREYKE, M.A.
The Hon. Sir W. R. GROVE. M.A., D.C.L., F.R.S.
Professor G. G. STOKES, M.A., D.C.L., LL.D., Sec. R.S.
Sir JOHN HAWKSHAW, C.E., F.R.S., F.G.S., F.R.G.S.
ALLEN THOMSON, Esq., M.D., LL.D., F.R.S. L. & E.
Professor ALLMAN, M.D., LL.D., F.R.S. L. & E., F.L.S.

PRESIDENT ELECT.

C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.I.C.E.

VICE-PRESIDENTS ELECT.

The Right Hon. the Lord MOUNT-TEMPLE.
Captain Sir F. J. EVANS, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty.
Colonel A. C. COOKE, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey.
WYNDHAM S. PORTAL, Esq.
Professor PRESTWICH, M.A., F.R.S., F.G.S., F.C.S.
F. A. ABEL, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department.
Professor DE CHAUMONT, M.D., F.R.S.
PHILIP LUTLEY SCLATER, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.

LOCAL SECRETARIES FOR THE MEETING AT SOUTHAMPTON.

C. W. A. JELLICOE, Esq. JOHN E. LE FEUVRE, Esq. MORRIS MILES, Esq.

LOCAL TREASURER FOR THE MEETING AT SOUTHAMPTON.

J. BLOUNT THOMAS, Esq.

ORDINARY MEMBERS OF THE COUNCIL.

ABEL, F. A., Esq., C.B., F.R.S.
ADAMS, Professor W. G., F.R.S.
BATEMAN, J. F., Esq., C.E., F.R.S.
CAYLEY, Professor, F.R.S.
DE LA RUE, WARREN, Esq., F.R.S.
EVANS, Captain Sir F. J., C.B., F.R.S.
EVANS, J., Esq., F.R.S.
FOSTER, Professor G. C., F.R.S.
GLAISHER, J. W. L., Esq., F.R.S.
HARCOURT A. VERNON, Esq., F.R.S.
HASTINGS, G. W., Esq., M.P.
HAWKSHAW, J. CLARKE, Esq., F.G.S.
HEYWOOD, J., Esq., F.R.S.
HUGGINS, W., Esq., F.R.S.
HUGHES, Professor T. McK., F.G.S.
JEFFREYS, J. GWYN, Esq., F.R.S.
NEWTON, Professor A., F.R.S.
PENGELLY, W., Esq., F.R.S.
PERKIN, W. H., Esq., F.R.S.
PITT-RIVERS, General A., F.R.S.
PRESTWICH, Professor, F.R.S.
RAYLEIGH, Lord, F.R.S.
SANDERSON, Prof. J. S. BURDON, F.R.S.
SORBY, Dr. H. C., F.R.S.
THUILLIER, Gen. Sir H. E. L., C.S.I., F.R.S.

GENERAL SECRETARIES.

Capt. DOUGLAS GALTON, C.B., D.C.L., F.R.S., F.G.S., 12 Chester Street, Grosvenor Place, London, S.W.
FRANCIS MAITLAND BALFOUR, Esq., M.A., LL.D., F.R.S., Trinity College, Cambridge.

SECRETARY.

Professor T. G. BONNEY, M.A., F.R.S., F.S.A., F.G.S., 22 Albemarle Street, London, W.

GENERAL TREASURER.

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

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, the President and President Elect, the Presidents of former years, the Vice-Presidents and Vice-Presidents Elect, the General and Assistant General Secretaries for the present and former years, the Secretary, the General Treasurers for the present and former years, and the Local Treasurer and Secretaries for the ensuing Meeting.

TRUSTEES (PERMANENT).

General Sir EDWARD SABINE, K.C.B., R.A., D.C.L., F.R.S.
Sir JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., Pres. R.S.

PRESIDENTS OF FORMER YEARS.

The Duke of Devonshire.
The Rev. T. R. Robinson, D.D.
Sir G. B. Airy.
General Sir E. Sabine, K.C.B.
The Earl of Harrowby.
The Duke of Argyll.
Dr. Richard Owen, D.C.L.
Sir W. G. Armstrong, C.B., LL.D.
Sir William R. Grove, F.R.S.
The Duke of Buccleuch, K.G.
Sir Joseph D. Hooker, K.C.S.I.
Prof. Stokes, M.A., D.C.L.
Prof. Huxley, LL.D., F.R.S.
Prof. Sir Wm. Thomson, D.C.L.
Dr. Carpenter, C.B., F.R.S.
Prof. Williamson, Ph.D., F.R.S.
Prof. Tyndall, D.C.L., F.R.S.
Sir John Hawkshaw, C.E., F.R.S.
Dr. T. Andrews, F.R.S.
Dr. Allen Thomson, F.R.S.
W. Spottiswoode, Esq., Pres. R.S.
Prof. Allman, M.D., F.R.S.
Sir A. C. Ramsay, LL.D., F.R.S.

GENERAL OFFICERS OF FORMER YEARS.

F. Galton, Esq., F.R.S.
Dr. T. A. Hirst, F.R.S.
Gen. Sir E. Sabine, K.C.B., F.R.S.
W. Spottiswoode, Esq., Pres. R.S.
Dr. Michael Foster, Sec. R.S.
George Griffith, Esq., M.A.
P. L. Sclater, Esq., F.R.S.

AUDITORS.

Dr. W. J. Russell, F.R.S. Professor G. C. Foster, F.R.S.

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1882.

---

* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of Residence should be sent to the Secretary, 22 *Albemarle Street, London,* W.

Year of Election.

Abbatt, Richard, F.R.A.S. Marlborough House, Burgess Hill, Sussex.
1866. ‡Abbott, George J., United States Consul, Sheffield and Nottingham.
1881. *Abbott, R. T. C. Auburn Hill, Malton, Yorkshire.
1863. *ABEL, FREDERICK AUGUSTUS, C.B., F.R.S., F.C.S., Director of the Chemical Establishment of the War Department. Royal Arsenal, Woolwich.
1856. ‡Abercrombie, John, M.D. 13 Suffolk-square, Cheltenham.
1863. *ABERNETHY, JAMES, M.Inst.C.E., F.R.S.E. 4 Delahay-street, Westminster, S.W.
1873. ‡Abernethy, James. Ferry-hill, Aberdeen.
1860. ‡Abernethy, Robert. Ferry-hill, Aberdeen.
1873. *ABNEY, Captain W. de W., R.E., F.R.S., F.R.A.S., F.C.S. 3 St. Alban's-road, Kensington, London, W.
1854. ‡Abraham, John. 87 Bold-street, Liverpool.
1877. §Ace, Rev. Daniel, D.D., F.R.A.S. Laughton, near Gainsborough, Lincolnshire.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.
1877. *Acland, Francis E. Dyke, R.A. Oxford.
1873. **Acland, Rev. H. D. Loughton, Essex.*
ACLAND, HENRY W. D., M.A., M.D., LL.D., F.R.S., F.R.G.S., Radcliffe Librarian and Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.

Year of Election.

1877. *Acland, Theodore Dyke, M.A. 13 Vincent-square, Westminster, S.W.

1860. ‡ACLAND, Sir THOMAS DYKE, Bart., M.A., D.C.L., M.P. Sprydoncote, Exeter; and Athenæum Club, London, S.W.

Adair, John. 13 Merrion-square North, Dublin.

1872. ‡ADAMS, A. LEITH, M.A. M.B., F.R.S., F.G.S., Professor of Natural History in Queen College, Cork. 18 Clarendon-gardens, Maida Hill, London, W.

1876. ‡Adams, James. 9 Royal-crescent West, Glasgow.

*ADAMS, JOHN COUCH, M.A., LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndsean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.

1871. ‡Adams, John R. 3 Queen's-gate-terrace, London, S.W.

1879. *ADAMS, Rev. THOMAS, M.A. Clifton Green House, York.

1877. ‡ADAMS, WILLIAM. 3 Sussex-terrace, Plymouth.

1869. *ADAMS, WILLIAM GRYLLS, M.A., F.R.S., F.G.S., F.C.P.S., Professor of Natural Philosophy and Astronomy in King's College, London. 43 Notting Hill-square, London, W.

1873. ‡Adams-Acton, John. Margutta House, 103 Marylebone-road, London, N.W.

1879. ‡Adamson, Robert, M.A., Professor of Logic and Political Economy in Owens College, Manchester. 60 Parsonage-road, Withington, Manchester.

ADDERLEY, The Right Hon. Sir CHARLES BOWYER. Hamshall, Coleshill, Warwickshire.

Adelaide, The Right Rev. Augustus Short, D.D., Bishop of. South Australia.

1865. *Adkins, Henry. Northfield, near Birmingham.

1864. *Ainsworth, David. The Flosh, Cleator, Carnforth.

1871. *Ainsworth, John Stirling. The Flosh, Cleator, Carnforth.

Ainsworth, Peter. Smithills Hall, Bolton.

1842. *Ainsworth, Thomas. The Flosh, Cleator, Carnforth.

1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.

1859. ‡AIRLIE, The Right Hon. the Earl of, K.T. Holly Lodge, Campden Hill, London, W.; and Airlie Castle, Forfarshire.

AIRY, Sir GEORGE BIDDELL, K.C.B., M.A., LL.D., D.C.L., F.R.S., F.R.A.S., The White House, Croom's Hill, Greenwich, S.E.

1871. §Aitken, John, F.R.S.E. Darroch, Falkirk, N.B.

Akroyd, Edward. Bankfield, Halifax.

1862. ‡ALCOCK, Sir RUTHERFORD, K.C.B., D.C.L., F.R.G.S. The Athenæum Club, Pall Mall, London, S.W.

1861. ‡Alcock, Thomas, M.D. Side Brook, Salemoor, Manchester.

1872. *Alcock, Thomas, M.D. Oakfield, Sale, Manchester.

*Aldam, William. Frickley Hall, near Doncaster.

ALDERSON, Sir JAMES, M.A., M.D., D.C.L., F.R.S., Consulting Physician to St. Mary's Hospital. 17 Berkeley-square, London, W.

1859. ‡ALEXANDER, General Sir JAMES EDWARD, K.C.B., K.C.L.S., F.R.S.E., F.R.A.S., F.R.G.S. Westerton, Bridge of Allan, N.B.

1873. ‡Alexander, Reginald, M.D. 13 Hallfield-road, Bradford, Yorkshire.

1858. ‡ALEXANDER, WILLIAM, M.D. Halifax.

1850. ‡Alexander, Rev. William Lindsay, D.D., F.R.S.E. Pinkieburn, Musselburgh, by Edinburgh.

1867. ‡Alison, George L. C. Dundee.

1859. ‡Allan, Alexander. Scottish Central Railway, Perth.

1871. ‡Allan, G., C.E. 17 Leadenhall-street, London, E.C.

1871. §ALLEN, ALFRED H., F.C.S. 1 Surrey-street, Sheffield.

Year of Election.

1879. *Allen, Rev. A. J. C. Peterhouse, Cambridge.
1878. ‡Allen, John Romilly. 5 Albert-terrace, Regent's Park, London, N.W.
1861. ‡Allen, Richard. Didsbury, near Manchester.
1852. *Allen, William J. C., Secretary to the Royal Belfast Academical Institution. Ulster Bank, Belfast.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
*Allman, George J., M.D., LL.D., F.R.S. L. & E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. Ardmoor, Parkstone, Dorset.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1876. ‡Anderson, Alexander. 1 St. James's-place, Hillhead, Glasgow.
1878. ‡Anderson, Beresford. Saint Ville, Killiney.
1850. ‡Anderson, Charles William. Cleadon, South Shields.
1850. ‡Anderson, John. 31 St. Bernard's-crescent, Edinburgh.
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1876. ‡Anderson, Matthew. 137 St. Vincent-street, Glasgow.
1859. ‡Anderson, Patrick. 15 King-street, Dundee.
1880. §§*Anderson, Richard. New Malden, Surrey.*
1875. ‡Anderson, Captain S., R.E. Junior United Service Club, Charles-street, St. James's, London, S.W.
1880. *Anderson, Tempest, M.D., B.Sc. 17 Stonegate, York.
1880. §Andrew, Mrs. 126 Jamaica-street, Stepney, London, E.
1880. *Andrew, Thornton, M.I.C.E. Cefn Eithen, Swansea.
*Andrews, Thomas, M.D., LL.D., F.R.S., Hon. F.R.S.E., M.R.I.A., F.C.S. Fortwilliam Park, Belfast.
1877. §Angell, John, F.C.S. 81 Ducie-grove, Oxford-street, Manchester.
1859. ‡Angus, John. Town House, Aberdeen.
1878. ‡Anson, Frederick H. 9 Delahay-street, Westminster, S.W.
Anthony, John, M.D. 6 Greenfield-crescent, Edgbaston, Birmingham.
Apjohn, James, M.D., F.R.S., F.C.S., M.R.I.A., Professor of Mineralogy at Dublin University. South Hill, Blackrock, Co. Dublin.
1868. ‡Appleby, C. J. Emerson-street, Bankside, Southwark, London, S.E.
1870. ‡Archer, Francis, jun. 3 Brunswick-street, Liverpool.
1855. *Archer, Professor Thomas C., F.R.S.E., Director of the Museum of Science and Art, Edinburgh. West Newington House, Edinburgh.
1874. ‡Archer, William, F.R.S., M.R.I.A. St. Brendan's, Grosvenor-road East, Rathmines, Dublin.
1851. ‡Argyll, His Grace the Duke of, K.T., D.C.L., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London, W.; and Inveraray, Argyleshire.
1861. ‡Armitage, William. 95 Portland-street, Manchester.
1867. *Armitstead, George. Errol Park, Errol, N.B.
1879. *Armstrong, Sir Alexander, K.C.B., LL.D., F.R.S., F.R.G.S. The Albany, London, W.
1873. §Armstrong, Henry E., Ph.D., F.R.S., F.C.S. London Institution, Finsbury-circus, London, E.C.
1878. ‡Armstrong, James. 28a Renfield-street, Glasgow.
1874. ‡Armstrong, James T., F.C.S. 17 The Willows, Breck-road, Liverpool.
Armstrong, Thomas. Higher Broughton, Manchester.
1857. *Armstrong, Sir William George, C.B., LL.D., D.C.L., F.R.S. 8 Great George-street, London, S.W.; and Jesmond Dene, Newcastle-upon-Tyne.
1870. ‡Arnott, Thomas Reid. Bramshill, Harlesden Green, London, N.W.

Year of Election.

1853. *Arthur, Rev. William, M.A. Clapham Common, London, S.W.
1870. *Ash, Dr. T. Linnington. Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.
1873. §Ashton, John. Gorse Bank House, Windsor-road, Oldham.
1842. *Ashton, Thomas, M.D. 8 Royal Wells-terrace, Cheltenham.
Ashton, Thomas. Ford Bank, Didsbury, Manchester.
1866. ‡Ashwell, Henry. Mount-street, New Basford, Nottingham.
*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
Ashworth, Henry. Turton, near Bolton.
1861. ‡Aspland, Alfred. Dukinfield, Ashton-under-Lyne.
1875. *Aspland, W. Gaskell. Care of Mrs. Houghton, Moorfield, Knutsford.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Theodore. 11 New-square, Lincoln's Inn, London, W.C.
1872. §Atchison, Arthur T., M.A. 60 Warwick-road, Earl's Court, London, S.W.
1858. ‡Atherton, Charles. Sandover, Isle of Wight.
1866. ‡*Atherton, J. H., F.C.S. Long-row, Nottingham.*
1865. ‡*Atkin, Alfred. Griffin's Hill, Birmingham.*
1861. ‡Atkin, Eli. Newton Heath, Manchester.
1865. *ATKINSON, EDMUND, Ph.D., F.C.S. Portesbery Hill, Camberley, Surrey.
1863. *Atkinson, G. Clayton. 21 Windsor-terrace, Newcastle-on-Tyne.
1861. ‡Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
1858. *Atkinson, John Hastings. 12 East Parade, Leeds.
1842. *Atkinson, Joseph Beavington. Stratford House, 113 Abingdon-road, Kensington, London, W.
1881. §Atkinson, J. T. The Quay, Selby, Yorkshire.
1881. §Atkinson Robert William. Town Hall-buildings, Newcastle-on-Tyne.
1858. Atkinson, William. Claremont, Southport.
1863. *ATTFIELD, Professor J., Ph.D., F.R.S., F.C.S. 17 Bloomsbury-square, London, W.C.
1860. *Austin-Gourlay, Rev. William E. C., M.A. The Rectory, Stanton St. John, near Oxford.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1881. §Axon, W. E. A. Fern Bank, Higher Broughton, Manchester.
1878. *Aylmer, Sir Gerald George, Bart. Donadea Castle, Kilcock, Co. Kildare.
1877. *Ayrton, W. E., F.R.S., Professor of Applied Physics in the City and Guilds of London Technical College. 68 Sloane-street, London, S.W.
1853. *Ayrton, W. S., F.S.A. Cliffden, Saltburn-by-the-Sea.

*BABINGTON, CHARLES CARDALE, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.
Backhouse, Edmund. Darlington.
Backhouse, Thomas James. Sunderland.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1877. ‡Badock, W. F. Badminton House, Clifton Park, Bristol.
1870. §Bailey, Dr. F. J. 51 Grove-street, Liverpool.
1878. ‡Bailey, John. 3 Blackhall-place, Dublin.
1865. ‡Bailey, Samuel, F.G.S. The Peck, Walsall.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1866. ‡Baillon, Andrew. St. Mary's Gate, Nottingham.

Year of Election.

1866. ‡Baillon, L. St. Mary's Gate, Nottingham.
1878. ‡Baily, Walter. 176 Haverstock-hill, London, N.W.
1857. ‡BAILY, WILLIAM HELLIER, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 14 Hume-street; and Apsley Lodge, 92 Rathgar-road, Dublin.
1873. §Bain, Sir James. 3 Park-terrace, Glasgow.
*Bainbridge, Robert Walton. Middleton House, Middleton-in-Teesdale, by Darlington.
*BAINES, Sir EDWARD, J.P. Belgrave Mansions, Grosvenor-gardens, London, S.W.; and St. Ann's Hill, Burley, Leeds.
1858. ‡Baines, Frederick. Burley, near Leeds.
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1866. ‡Baker, Francis B. Sherwood-street, Nottingham.
1865. ‡Baker, James P. Wolverhampton.
1861. *Baker, John. St. John's-road, Buxton.
1881. §Baker, Robert, M.D. The Retreat, York.
1865. ‡Baker, Robert L. Barham House, Leamington.
1849. *Baker, William. 63 Gloucester-place, Hyde Park, London, W.
1863. ‡Baker, William. 6 Taptonville, Sheffield.
1875. *Baker, W. Mills. Moorland House, Stoke Bishop, near Bristol.
1875. ‡BAKER, W. PROCTOR. Brislington, Bristol.
1881. §Baldwin, Rev. G. W. de Courcy, M.A. Lord Mayor's Walk, York.
*Barnett, Richard, M.R.C.S. 36 High Street, Warwick.
1871. *BALFOUR, FRANCIS MAITLAND, M.A., LL.D., F.R.S. (GENERAL SECRETARY.) Trinity College, Cambridge.
1871. ‡Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
1875. ‡BALFOUR, ISAAC BAYLEY, D.Sc. 27 Inverleith-row, Edinburgh.
*BALFOUR, JOHN HUTTON, M.A., M.D., LL.D., F.R.S. L. & E., F.L.S. Emeritus Professor of Botany. Inverleith House, Edinburgh.
1878. *Ball, Charles Bent, M.D. 16 Lower Fitzwilliam-street, Dublin.
*BALL, JOHN, M.A., F.R.S., F.L.S., M.R.I.A. 10 Southwell-gardens, South Kensington, London, S.W.
1866. *BALL, ROBERT STAWELL, M.A., LL.D., F.R.S., F.R.A.S., Andrews Professor of Astronomy in the University of Dublin, and Astronomer Royal for Ireland. The Observatory, Dunsink, Co. Dublin.
1878. ‡BALL, VALENTINE, M.A., F.G.S., Professor of Geology in Trinity College, Dublin.
1876. ‡*Ballantyne, James. Southcroft, Rutherglen, Glasgow.*
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1852. ‡Bangor, Viscount. Castleward, Co. Down, Ireland.
1879. ‡Banham, H. French. Mount View, Glossop-road, Sheffield.
1870. ‡BANISTER, Rev. WILLIAM, B.A. St. James's Mount, Liverpool.
1866. ‡Barber, John. Long-row, Nottingham.
1861. *Barbour, George. Bankhead, Broxton, Chester.
1859. ‡Barbour, George F. 11 George-square, Edinburgh.
*Barbour, Robert. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
Barclay, Charles, F.S.A. Bury Hill, Dorking.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1876. *Barclay, Robert. 21 Park-terrace, Glasgow.
1868. *Barclay, W. L. 54 Lombard-street, London, E.C.
1881. §Barfoot, William, J.P. Whelford-place, Leicester.

Year of Election.

1863. *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.
1879. ‡Barker, Elliott. 2 High-street, Sheffield.
1879. *Barker, Rev. Philip C., M.A., LL.B. Rotherham, Yorkshire.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870.§§Barkly, Sir Henry, G.C.M.G., K.C.B., F.R.S., F.R.G.S. 1 Bina-gardens, South Kensington, London, S.W.
1873. ‡Barlow, Crawford, B.A. 2 Old Palace-yard, Westminster, S.W.
1878. ‡Barlow, John, M.D., Professor of Physiology in Anderson's College, Glasgow.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
1857. ‡Barlow, Peter William, F.R.S., F.G.S. 26 Great George-street, Westminster, S.W.
1873. §Barlow, W. H., C.E., F.R.S. 2 Old Palace-yard, Westminster, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1868. §Barnes, Richard H. (Care of Messrs. Collyer, 4 Bedford-row, London, W.C.)
Barnes, Thomas Addison. Brampton Collieries, near Chesterfield.
*Barnett, Richard, M.R.C.S. 36 High-street, Warwick.
1881. §Barr, Archibald, B.Sc., C.E. Castlehead, Paisley.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1861. *_Barr, William R., F.G.S. Fernside, Cheadle Hulme, Cheshire._
1860. ‡Barrett, T. B. High-street, Welshpool, Montgomery.
1872. *Barrett, W. F., F.R.S.E., M.R.I.A., F.C.S., Professor of Physics in the Royal College of Science, Dublin.
1874. ‡Barrington, R. M. Fassaroe, Bray, Co. Wicklow.
1874. §Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Salwarpe End, Droitwich.
1881. §Barron, G.B., M.D. Summerseat, Southport.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1858. ‡Barry, Rev. Canon, D.D., D.C.L., Principal of King's College, London, W.C.
1862. *Barry, Charles. 15 Pembridge-square, Bayswater, London, W.
1875. ‡Barry, John Wolfe. 23 Delahay-street, Westminster, S.W.
1881. §Barry, J. W. Duncombe-place, York.
Barstow, Thomas. Garrow Hill, near York.
1858. *Bartholomew, Charles. Castle Hill House, Ealing, Middlesex, W.
1855. ‡Bartholomew, Hugh. New Gasworks, Glasgow.
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Headingley, Leeds.
1873. §Bartley, George C. T. St. Margaret's House, Victoria-street, London, S.W.
1868. *Barton, Edward (27th Inniskillens). Clonelly, Ireland.
1857. ‡Barton, Folloit W. Clonelly, Co. Fermanagh.
1852. ‡Barton, James. Farndreg, Dundalk.
1864. ‡Bartrum, John S. 41 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1876. ‡Bassano, Alexander. 12 Montagu-place, London, W.
1876. ‡Bassano, Clement. Jesus College, Cambridge.
1866. *Bassett, Henry. 26 Belitha-villas, Barnsbury, London, N.
1866. ‡Bassett, Richard. Pelham-street, Nottingham.
1869. ‡Bastard, S. S. Summerland-place, Exeter.

Year of Election.

1871. ‡Bastian, H. Charlton, M.D., M.A., F.R.S., F.L.S., Professor of Pathological Anatomy at University College. 20 Queen Anne-street, London, W.
1848. ‡Bate, C. Spence, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.
1873. *Bateman, Daniel. Low Moor, near Bradford, Yorkshire.
1868. ‡Bateman, Frederick, M.D. Upper St. Giles's-street, Norwich.
Bateman, James, M.A., F.R.S., F.R.G.S., F.L.S. 9 Hyde Park-gate South, London, W.
1842. *Bateman, John Frederic, C.E., F.R.S., F.G.S., F.R.G.S. 16 Great George-street, London, S.W.
1864. ‡Bates, Henry Walter, F.R.S., Assist.-Sec. R.G.S., F.L.S. 1 Savile-row, London, W.
1852. ‡Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1851. ‡Bath and Wells, The Right Rev. Lord Arthur Hervey, Lord Bishop of. The Palace, Wells, Somerset.
1881. §Bather, Francis A. Red House, Roehampton, Surrey, S.W.
1869. ‡Batten, John Winterbotham. 35 Palace Gardens-terrace, Kensington, London, W.
1863. §Bauerman, H., F.G.S. 41 Acre-lane, Brixton, London, S.W.
1861. ‡Baxendell, Joseph, F.R.A.S. 108 Stock-street, Manchester.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1867. ‡Baxter, John B. Craig Tay House, Dundee.
1867. ‡Baxter, The Right Hon. William Edward, M.P. Ashcliffe, Dundee.
1868. ‡Bayes, William, M.D. 58 Brook-street, London, W.
1851. *Bayley, George. 16 London-street, Fenchurch-street, London, E.C.
1866. ‡Bayley, Thomas. Lenton, Nottingham.
Bayly, John. Seven Trees, Plymouth.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
Bazley, Thomas Sebastian, M.A. Hatherop Castle, Fairford, Gloucestershire.
1860. *Beale, Lionel S., M.D., F.R.S., Professor of Pathological Anatomy in King's College. 61 Grosvenor-street, London, W.
1872. ‡Beanes, Edward, F.C.S. The White House, North Dulwich, Surrey, S.E.
1870. ‡Beard, Rev. Charles. 13 South-hill-road, Toxteth Park, Liverpool.
*Beatson, William. Ash Mount, Rotherham.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.M.S., F.S.S. 18 Piccadilly, London, W.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1871. *Beazley, Lieut.-Colonel George G., F.R.G.S. Army and Navy Club, Pall Mall, London, S.W.
1859. *Beck, Joseph, F.R.A.S. 31 Cornhill, London, E.C.
1864. §Becker, Miss Lydia E. Whalley Range, Manchester.
1860. ‡Beckles, Samuel H., F.R.S., F.G.S. 9 Grand-parade, St. Leonard's-on-Sea.
1866. ‡Beddard, James. Derby-road, Nottingham.
1870. §Beddoe, John, M.D., F.R.S. Clifton, Bristol.
1858. ‡Bedford, James. Headingley, near Leeds.
1878. ‡Bedson, P. Phillips, D.Sc. Oak Leigh, Marple, near Stockport.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1873. ‡Bell, A. P. Royal Exchange, Manchester.
1871. §Bell, Charles B. 6 Spring-bank, Hull.

Year of Election.

Bell, Frederick John. Woodlands, near Maldon, Essex.
1859. ‡Bell, George. Windsor-buildings, Dumbarton.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.
1855. ‡*Bell, Capt. Henry. Chalfont Lodge, Cheltenham.*
1880. §Bell, Henry Oswin. 13 Northumberland-terrace, Tynemouth.
1879. ‡Bell, Henry S. Kenwood Bank, Sharrow, Sheffield.
1862. *BELL, ISAAC LOWTHIAN, F.R.S., F.C.S., M.I.C.E. Rounton Grange, Northallerton.
1875. ‡Bell, James, F.C.S. The Laboratory, Somerset House, London, W.C.
1871. *Bell, J. Carter, F.C.S. Kersal Clough, Higher Broughton, Manchester.
1853. ‡Bell, John Pearson, M.D. Waverley House, Hull.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1876. ‡*Bell, R. Bruce. 2 Clifton-place, Glasgow.*
1863. *Bell, Thomas. Crosby Court, Northallerton.
1867. ‡Bell, Thomas. Belmont, Dundee.
1875. ‡Bell, William. Witford House, Briton Ferry, Glamorganshire.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1864. *Bendyshe, T. 3 Sea-View-terrace, Margate.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1836. ‡Bennett, Henry. Bedminster, Bristol.
1881. §Bennett, John R. Bedminster, Bristol.
1881. §Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishophill Junior, York.
1870. *Bennett, William. 109 Shaw-street, Liverpool.
1870. *Bennett, William, jun. Oak Hill Park, Old Swan, near Liverpool.
1852. *Bennoch, Francis, F.S.A. 5 Tavistock-square, London, W.C.
Benson, Robert, jun. Fairfield, Manchester.
1848. ‡Benson, Starling, F.G.S. Gloucester-place, Swansea.
1870. ‡Benson, W. Alresford, Hants.
1863. ‡Benson, William. Fourstones Court, Newcastle-on-Tyne.
1848. ‡BENTHAM, GEORGE, F.R.S., F.R.G.S., F.L.S. 25 Wilton-place, Knightsbridge, London, S.W.
1842. Bentley, John. 2 Portland-place, London, W.
1863. §BENTLEY, ROBERT, F.L.S., Professor of Botany in King's College, London. 1 Trebovir-road, South Kensington, London, S.W.
1875. ‡*Beor, Henry R. Scientific Club, Savile-row, London, W.*
1876. ‡Bergius, Walter C. 9 Loudon-terrace, Hillhead, Glasgow.
1868. ‡BERKELEY, Rev. M. J., M.A., F.R.S., F.L.S. Sibbertoft, Market Harborough.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1881. §Berkley, H. Rorke. Prestwich, Manchester.
1848. ‡Berrington, Arthur V. D. Woodlands Castle, near Swansea.
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A., F.R.S. St. John's College, Cambridge.
1865. *BESSEMER, Sir HENRY, F.R.S. Denmark Hill, London, S.E.
1858. ‡Best, William. Leydon-terrace, Leeds.
Bethune, Admiral, C.B., F.R.G.S. Balfour, Fifeshire.
1876. *Bettany, G. T., M.A., B.Sc., Lecturer on Botany at Guy's Hospital, London. 2 Eckington-villas, Ashbourne-grove, East Dulwich, S.E.

Year of Election.

1880. *Bevan, Rev. James Oliver, M.A. 72 Beaufort-road, Edgbaston, Birmingham.
1859. ‡Beveridge, Robert, M.B. 36 King-street, Aberdeen.
1874. *Bevington, James B. Merle Wood, Sevenoaks.
1863. ‡Bewick, Thomas John, F.G.S. Haydon Bridge, Northumberland.
*Bickerdike, Rev. John, M.A. Shireshead Vicarage, Garstang.
1870. ‡Bickerton, A.W., F.C.S. Christchurch, Canterbury, New Zealand.
1863. ‡Bigger, Benjamin. Gateshead, Durham.
1864. ‡Biggs, Robert. 16 Green Park, Bath.
Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.
1877. ‡*Binder, W. J., B.A. Barnsley.*
1881. §Binnie, Alexander R. Town Hall, Bradford, Yorkshire.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
1879. ‡Binns, E. Knowles. 216 Heavygate-road, Sheffield.
Birchall, Edwin, F.L.S. Douglas, Isle of Man.
Birchall, Henry. College House, Bradford.
1880. §Bird, Henry, F.C.S. South Down, near Devonport.
1866. *Birkin, Richard. Aspley Hall, near Nottingham.
*Birks, Rev. Thomas Rawson, M.A., Professor of Moral Philosophy in the University of Cambridge. 6 Salisbury-villas, Cambridge.
1871. *Bischof, Gustav. 4 Hart-street, Bloomsbury, London, W.C.
1868. ‡Bishop, John. Thorpe Hamlet, Norwich.
1866. ‡Bishop, Thomas. Bramcote, Nottingham.
1877. ‡Blachford, The Right Hon. Lord, K.C.M.G. Cornwood, Ivybridge.
1881. §Black, W. J. United Service Club, Edinburgh.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1834. Blackburn, Bewicke. 14 Victoria-road, Kensington, London, W.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
Blackburne, Rev. John, M.A. Yarmouth, Isle of Wight.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1859. ‡Blackie, John Stewart, M.A., Professor of Greek in the University of Edinburgh.
1876. ‡Blackie, Robert. 7 Great Western-terrace, Glasgow.
1855. *Blackie, W. G., Ph.D., F.R.G.S. 17 Stanhope-street, Glasgow.
1870. ‡Blackmore, W. Founder's-court, Lothbury, London, E.C.
1878. §Blair, Matthew. Oakshaw, Paisley.
1863. ‡Blake, C. Carter, D.Sc. Westminster Hospital School of Medicine, Broad Sanctuary, Westminster, S.W.
1849. *Blake, Henry Wollaston, M.A., F.R.S., F.R.G.S. 8 Devonshire-place, Portland-place, London, W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1878. ‡Blakeney, Rev. Canon, M.A., D.D. The Vicarage, Sheffield.
1861. §Blakiston, Matthew, F.R.G.S. 18 Wilton-crescent, London, S.W.
1881. §Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1869. ‡Blanford, W. T., F.R.S., F.G.S., F.R.G.S. Geological Survey of India, Calcutta.
*Blomefield, Rev. Leonard, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
1880. §Bloxam, G. W., M.A., F.L.S. 44 Dacre-park, Lee, Kent.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Capt. Richard. Bretlands, Chertsey, Surrey.

Year of Election.

Blyth, B. Hall. 135 George-street, Edinburgh.
1858. *Blythe, William. Holland Bank, Church, near Accrington.
1867. ‡Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1870. ‡Boardman, Edward. Queen-street, Norwich.
1866. §*Bogg, Thomas Wemyss. 2 East Ascent, St. Leonard's.*
1859. *Bohn, Henry G., F.L.S., F.R.A.S., F.R.G.S., F.S.S. North End House, Twickenham.
1871. ‡Bohn, Mrs. North End House, Twickenham.
1881. §Bojanowski, Dr. Victor de, Consul-General for Germany. 27 Finsbury-circus, London, E.C.
1859. ‡Bolster, Rev. Prebendary John A. Cork.
1876. ‡Bolton, J. C. Carbrook, Stirling.
Bolton, R. L. Laurel Mount, Aigburth-road, Liverpool.
1866. ‡Bond, Banks. Low Pavement, Nottingham.
Bond, Henry John Hayes, M.D. Cambridge.
1871. §Bonney, Rev. Thomas George, M.A., F.R.S., F.S.A., F.G.S. Professor of Geology in University College, London. (Secretary.) 23 Denning-road, Hampstead, London, N.W.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. §Booth, James. Elmfield, Rochdale.
1861. *Booth, William. Hollybank, Cornbrook, Manchester.
1876. ‡Booth, William H. Trinity College, Oxford.
1880. §§Boothroyd, Samuel. Warley House, Southport.
1861. *Borchardt, Louis, M.D. Barton Arcade, Manchester.
1849. ‡Boreham, William W., F.R.A.S. The Mount, Haverhill, Newmarket.
1876. *Borland, William. 260 West George-street, Glasgow.
1863. ‡*Borries, Theodore. Lovaine-crescent, Newcastle-on-Tyne.*
1876. *Bosanquet, R. H. M., M.A., F.C.S., F.R.S.A. St. John's College, Oxford.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1881. §Bothamley, Charles H. Yorkshire College, Leeds.
1867. §Botly, William, F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1871. *Bottomley, James Thomson, M.A., F.R.S.E., F.C.S. 2 Eton-terrace, Hillhead, Glasgow.
Bottomley, William. 14 Brunswick-gardens, Kensington, London, W.
1876. ‡Bottomley, William, jun. 14 Brunswick-gardens, Kensington, London, W.
1870. ‡Boult, Swinton. 1 Dale-street, Liverpool.
1868. ‡Boulton, W. S. Norwich.
1866. §Bourne, Stephen, F.S.S. Abberley, Wallington, Surrey.
1872. ‡Bovill, William Edward. 29 James-street, Buckingham-gate, London, S.W.
1870. ‡Bower, Anthony. Bowersdale, Seaforth, Liverpool.
1881. *Bower, F. O. Elmscroft, Ripon, Yorkshire.
1867. ‡Bower, Dr. John. Perth.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1880. §Bowly, Christopher. Cirencester.
1863. ‡Bowman, R. Benson. Newcastle-on-Tyne.
Bowman, William, F.R.S., F.R.C.S. 5 Clifford-street, London, W
1869. ‡Bowring, Charles T. Elmsleigh, Prince's-park, Liverpool.
1863. ‡Boyd, Edward Fenwick. Moor House, near Durham.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.

Year of Election.

1865. ‡BOYLE, The Very Rev. G. D., M.A., Dean of Salisbury. The Deanery, Salisbury.
1872. *BRABROOK, E. W., F.S.A., Dir. A.I. 28 Abingdon-street, Westminster, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Cathcart House, Cathcart-road, London, S.W.
1870. ‡*Brace, Edmund.* 3 *Spring-gardens, Kelvinside, Glasgow.*
Bracebridge, Charles Holt, F.R.G.S. The Hall, Atherstone, Warwickshire.
1880. §Bradford, H. Stretton House, Walters-road, Swansea.
1861. *Bradshaw, William. Slade House, Green-walk, Bowdon, Cheshire.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
Brady, Daniel F., M.D. 5 *Gardiner's-row, Dublin.*
1863. ‡BRADY, GEORGE S., M.D., F.L.S., Professor of Natural History in the College of Physical Science, Newcastle-on-Tyne. 22 Fawcett-street, Sunderland.
1862. §BRADY, HENRY BOWMAN, F.R.S., F.L.S., F.G.S. Hillfield, Gateshead.
1880. *Brady, Rev. Nicholas, M.A. Wennington, Essex.
1875. ‡Bragge, William, F.S.A., F.G.S. Shirle Hill, Birmingham.
1864. §Braham, Philip, F.C.S. 6 George-street, Bath.
1870. ‡Braidwood, Dr. Delemere-terrace, Birkenhead.
1864. §Braikenridge, Rev. George Weare, M.A., F.L.S. Clevedon, Somerset.
1879. ‡Bramley, Herbert. Claremont-crescent, Sheffield.
1865. §BRAMWELL, Sir FREDERICK J., M.I.C.E., F.R.S. 37 Great George-street, London, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. Dickleburgh Rectory, Scole, Norfolk.
1852. ‡BRAZIER, JAMES S., F.C.S., Professor of Chemistry in Marischal College and University of Aberdeen.
1857. ‡*Brazill, Thomas.* 12 *Holles-street, Dublin.*
1869. *BREADALBANE, The Right Hon. the Earl of. Taymouth Castle, N.B.; and Carlton Club, Pall Mall, London, S.W.
1873. §Breffit, Edgar. 83 Upper Thames-street, London, E.C.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1877. ‡Brent, Francis. 19 Clarendon-place, Plymouth.
1881. *Brett, Alfred Thomas, M.D. Watford House, Watford.
1860. ‡Brett, G. Salford.
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1875. §Briant, T. Hampton Wick, Kingston-on-Thames.
1867. ‡BRIDGMAN, WILLIAM KENCELEY. 69 St. Giles's-street, Norwich.
1870. *Bridson, Joseph R. Belle Isle, Windermere.
1870. ‡Brierley, Joseph, C.E. New Market-street, Blackburn.
1879. §Brierley, Morgan. Denshaw House, Saddleworth.
1870. *BRIGG, JOHN. Broomfield, Keighley, Yorkshire.
1866. *Briggs, Arthur. Cragg Royd, Rawdon, near Leeds.
1863. *BRIGHT, Sir CHARLES TILSTON, C.E., F.G.S., F.R.G.S., F.R.A.S. 20 Bolton-gardens, London, S.W.
1870. ‡Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
BRIGHT, The Right Hon. JOHN, M.P. Rochdale, Lancashire.
1868. ‡*Brine, Commander Lindesay. Army and Navy Club, Pall Mall, London, S.W.*
1879. ‡Brittain, Frederick. Taptonville-crescent, Sheffield.
1879. *BRITTAIN, W. H. Storth Oaks, Ranmoor, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, London, W.C.

Year of Election.

1859. *BRODHURST, BERNARD EDWARD, F.R.C.S., F.L.S. 20 Grosvenor-street, Grosvenor-square, London, W.
1865. ‡BRODIE, Rev. PETER BELLENGER, M.A., F.G.S. Rowington Vicarage, near Warwick.
1853. ‡Bromby, J. H., M.A. The Charter House, Hull.
1878. *Brook, George, F.L.S. Fernbrook, Huddersfield, Yorkshire.
1880. §§Brook, G. B. Brynsyfi, Swansea.
1881. §Brook, Robert G. Rowen-street, St. Helen's, Lancashire.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. J. Ingham. Thornhill Rectory, Dewsbury.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1878. ‡Brooke, Sir Victor, Bart., F.L.S. Colebrook, Brookeborough, Co. Fermanagh.
1863. ‡Brooks, John Crosse. Wallsend, Newcastle-on-Tyne.
1846. *Brooks, Thomas. Cranshaw Hall, Rawtenstall, Manchester.
Brooks, William. Ordfall Hill, East Retford, Nottinghamshire.
1874. ‡Broom, William. 20 Woodlands-terrace, Glasgow.
1847. ‡Broome, C. Edward, F.L.S. Elmhurst, Batheaston, near Bath.
1863. *BROWN, ALEXANDER CRUM, M.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1867. ‡Brown, Charles Gage, M.D. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. 93 Abbey-hill, Edinburgh.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1881. §Brown, Frederick D. 26 St. Giles's-street, Oxford.
1870. §BROWN, HORACE T. The Bank, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1870. *BROWN, J. CAMPBELL, D.Sc., F.C.S. Royal Infirmary School of Medicine, Liverpool.
1876. §Brown, John. Osborne Park, Belfast.
1881. *Brown, John, M.D. 66 Bank-parade, Burnley, Lancashire.
1859. ‡Brown, Rev. John Crombie, LL.D., F.L.S. Berwick-on-Tweed.
1874. ‡Brown, John S. Edenderry, Shaw's Bridge, Belfast.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
1871. ‡BROWN, ROBERT, M.A., Ph.D., F.L.S., F.R.G.S. 26 Guildford-road, Albert-square, London, S.W.
1868. ‡Brown, Samuel. Grafton House, Swindon, Wilts.
*Brown, Thomas. Evesham Lawn, Pittville, Cheltenham.
*Brown, William. 11 Maiden-terrace, Dartmouth Park, London, N.
1855. ‡Brown, William. 33 Berkeley-terrace, Glasgow.
1850. ‡Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.
1865. ‡Brown, William. 41A New-street, Birmingham.
1879. ‡Browne, J. Crichton, M.D., LL.D., F.R.S.E. 7 Cumberland-terrace, Regent's Park, London, N.W.
1866. *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.
1862. *Browne, Robert Clayton, jun., B.A. Browne's Hill, Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Northside, St. John's, Sevenoaks, Kent.
1875. ‡*Browne, Walter R. Bridgwater.*
1865. *Browne, William, M.D. The Friary, Lichfield.
1865. ‡Browning, John, F.R.A.S. 63 Strand, London, W.C.
1855. ‡Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.
1863. *Brunel, H. M. 23 Delahay-street, Westminster, S.W.
1863. ‡Brunel, J. 23 Delahay-street, Westminster, S.W.
1875. *Brunlees, James, C.E., F.G.S. 5 Victoria-street, Westminster, S.W.

Year of
Election.

1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.
1868. ‡BRUNTON, T. LAUDER, M.D., F.R.S. 50 Welbeck-street, London, W.
1878. §Brutton, Joseph. Yeovil.
1877. ‡Bryant, George. 82 Claverton-street, Pimlico, London, S.W.
1875. ‡Bryant, G. Squier. 15 White Ladies'-road, Clifton, Bristol.
1875. ‡Bryant, Miss S. A. The Castle, Denbigh.
1861. ‡Bryce, James. York-place, Higher Broughton, Manchester.
BRYCE, Rev. R. J., LL.D., Principal of Belfast Academy. Belfast.
1859. ‡Bryson, William Gillespie. Cullen, Aberdeen.
1867. ‡BUCCLEUCH AND QUEENSBERRY, His Grace the Duke of, K.G., D.C.L., F.R.S. L. & E., F.L.S. Whitehall-gardens, London, S.W.; and Dalkeith House, Edinburgh.
1871. §BUCHAN, ALEXANDER, M.A., F.R.S.E., Sec. Scottish Meteorological Society. 72 Northumberland-street, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
BUCHANAN, ANDREW, M.D., Professor of the Institutes of Medicine in the University of Glasgow. 4 Ethol-place, Glasgow.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. Poulton-cum-Seacombe, Cheshire.
1881. §Buchanan, J. H., M.D. Sowerby, Thirsk.
1871. ‡BUCHANAN, JOHN YOUNG. 10 Moray-place, Edinburgh.
1864. §BUCKLE, Rev. GEORGE, M.A. The Rectory, Weston-super-Mare.
1865. *Buckley, Henry. 27 Wheeley's-road, Edgbaston, Birmingham.
1848. *BUCKMAN, Professor JAMES, F.L.S., F.G.S. Bradford Abbas, Sherborne, Dorsetshire.
1880. §Buckney, Thomas, F.R.A.S. Little Thurlow, Suffolk.
1869. ‡Bucknill, J. C., M.D., F.R.S. 39 Wimpole-street, London, W.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1848. *BUDD, JAMES PALMER. Ystalyfera Iron Works, Swansea.
1875. §Budgett, Samuel. Cotham House, Bristol.
1871. ‡Bulloch, Matthew. 4 Bothwell-street, Glasgow.
1881. §Bulmer, T. P. Mount-villas, York.
1845. *BUNBURY, Sir CHARLES JAMES FOX, Bart., F.R.S., F.L.S., F.G.S., F.R.G.S. Barton Hall, Bury St. Edmunds.
1865. ‡Bunce, John Mackray. 'Journal' Office, New-street, Birmingham.
1863. §Bunning, T. Wood. Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne.
1842. *Burd, John. 5 Gower-street, London, W.C.
1875. ‡Burder, John, M.D. 7 South-parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, London, W.
1881. §Burdett-Coutts, W. L. A. B. 1 Stratton-street, Piccadilly, London, W.
1874. ‡Burdon, Henry, M.D. Clandeboye, Belfast.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1859. ‡Burnett, Newell. Belmont-street, Aberdeen.
1877. ‡Burns, David, C.E. Alston, Carlisle.
1881. §Burnure, William. Harlow, Essex.
1881. §Burroughs, S. M. 7 Snow-hill, London, E.C.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1877. ‡Burt, J. Kendall. Kendal.
1874. ‡Burt, Rev. J. T. Broadmoor, Berks.
1866. *BURTON, FREDERICK M., F.G.S. Highfield, Gainsborough.
1879. ‡Bury, Percy B. Cambridge.

Year of Election.

1864. ‡Bush, W. 7 Circus, Bath.
Bushell, Christopher. Royal Assurance-buildings, Liverpool.
1855. *Busk, George, F.R.S., F.L.S., F.G.S. 32 Harley-street, Cavendish-square, London, W.
1878. ‡Butcher, J. G., M.A. 22 Collingham-place, London, S.W.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1870. ‡Buxton, David, Ph.D. 298 Regent-street, London, W.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1881. §Buxton, Sydney. 7 Grosvenor-crescent, London, S.W.
1872. ‡Buxton, Sir T. Fowell, Bart. Warlies, Waltham Abbey, Essex.
1854. ‡Byerley, Isaac, F.L.S. Seacombe, Liverpool.
Byng, William Bateman. 2 Bank-street, Ipswich.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1875.§§Byrom, W. Ascroft, F.G.S. 31 King-street, Wigan.

1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1858. *Caine, Rev. William, M.A. Christ Church Rectory, Denton, near Manchester.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1876. ‡Caird, Edward B. 8 Scotland-street, Glasgow.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1855. *Caird, James Tennant. Belleaire, Greenock.
1875. ‡Caldicott, Rev. J. W., D.D. The Grammar School, Bristol.
1877. ‡Caldwell, Miss. 2 Victoria-terrace, Portobello, Edinburgh.
1868. ‡Caley, A. J. Norwich.
1868. ‡Caley, W. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1853. ‡Calver, Captain E. K., R.N., F.R.S. The Grange, Redhill, Surrey.
1876. ‡Cameron, Charles, M.D., LL.D., M.P. 1 Huntly-gardens, Glasgow.
1857. ‡Cameron, Charles A., M.D. 15 Pembroke-road, Dublin.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1881. §Cameron, Major-General, C.B. 3 Driffield-terrace, York.
1857. *Campbell, Dugald, F.C.S. 7 Quality-court, Chancery-lane, London, W.C.
1874. *Campbell, Sir George, K.C.S.I., M.P., D.C.L., F.R.G.S. 13 Cornwall-gardens, South Kensington, London, S.W.; and Edenwood, Cupar, Fife.
Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
1876. ‡Campbell, James A. 3 Claremont-terrace, Glasgow.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1872. ‡Campbell, Rev. J. R., D.D. 5 Eldon-place, Manningham-lane, Bradford, Yorkshire.
1859. ‡Campbell, William. Dunmore, Argyllshire.
1871. ‡Campbell, William Hunter, LL.D. Georgetown, Demerara, British Guiana. (Messrs. Ridgway & Sons, 2 Waterloo-place, London, S.W.)
Campbell-Johnston, Alexander Robert, F.R.S. 84 St. George's-square, London, S.W.
1876. §Campion, Frank, F.G.S., F.R.G.S. The Mount, Duffield-road, Derby.
1862. *Campion, Rev. Dr. William M. Queen's College, Cambridge.
1868. *Cann, William. 9 Southernhay, Exeter.
1880.§§Capper, Robert. Cwm Donkin, Swansea.
1873. *Carbutt, Edward Hamer, M.P., C.E. 19 Hyde Park-gardens, London, W.

Year of Election.

*Carew, William Henry Pole. Antony, Torpoint, Devonport.
1877. ‡Carkeet, John, C.E. 3 St. Andrew's-place, Plymouth.
1876. ‡Carlile, Thomas. 5 St. James's-terrace, Glasgow.
CARLISLE, The Right Rev. HARVEY GOODWIN, D.D., Lord Bishop of Carlisle.
1861. ‡Carlton, James. Mosley-street, Manchester.
1867. ‡Carmichael, David (Engineer). Dundee.
1867. ‡Carmichael, George. 11 Dudhope-terrace, Dundee.
1876. ‡Carmichael, Neil, M.D. 22 South Cumberland-street, Glasgow.
1871. ‡CARPENTER, CHARLES. Brunswick-square, Brighton.
1871. *CARPENTER, P. HERBERT, M.A. Eton College, Windsor.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1845. ‡CARPENTER, WILLIAM B., C.B., M.D., LL.D., F.R.S., F.L.S., F.G.S. 56 Regent's Park-road, London, N.W.
1872. §CARPENTER, WILLIAM LANT, B.A., B.Sc., F.C.S. 56 Regent's Park-road, London, N.W.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. British Museum, London, W.C.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1857. ‡CARTE, ALEXANDER, M.D. Museum of Science and Art, Dublin.
1868. ‡Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, C.E., F.G.S. Cockerham Hall, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 62 Elizabeth-street, Liverpool.
1878. *Cartwright, E. Henry. Magherafelt Manor, Co. Derry.
1870. §Cartwright, Joshua, A.I.C.E., Borough Surveyor. Bury, Lancashire.
1862. ‡Carulla, Facundo, F.A.S.L. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.
1868. ‡Cary, Joseph Henry. Newmarket-road, Norwich.
1866. ‡Casella, L. P., F.R.A.S. 147 Holborn Bars, London, E.C.
1878. ‡Casey, John, LL.D., F.R.S., M.R.I.A., Professor of Higher Mathematics in the Catholic University of Ireland. 2 Iona-terrace, South Circular-road, Dublin.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 38 Elmfield-terrace, Saville Park, Halifax.
Castle, Charles. Clifton, Bristol.
1874. ‡Caton, Richard, M.D., Lecturer on Physiology at the Liverpool Medical School. 18A Abercromby-square, Liverpool.
1853. ‡*Cator, John B., Commander R.N. 1 Adelaide-street, Hull.*
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1873. *Cavendish, Lord Frederick, M.P. 21 Carlton House-terrace, London, S.W.
1849. ‡Cawley, Charles Edward. The Heath, Kirsall, Manchester.
1860. §CAYLEY, ARTHUR, LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Mathemathics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1879. §Chadburn, Alfred. Brincliffe Rise, Sheffield.
1870. ‡Chadburn, C. H. Lord-street, Liverpool.
1858. *Chadwick, Charles, M.D. Lynncourt, Broadwater Down, Tunbridge Wells.
1860. ‡CHADWICK, DAVID. The Poplars, Herne Hill, London, S.E.
1842. CHADWICK, EDWIN, C.B. Richmond, Surrey.

Year of Election.

1859. ‡Chadwick, Robert. Highbank, Manchester.

*Challis, Rev. James, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy in the University of Cambridge. 2 Trumpington-street, Cambridge.

1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.

1865. ‡Chamberlain, J. H. Christ Church-buildings, Birmingham.

1842. Chambers, George. High Green, Sheffield.

1868. ‡Chambers, W. O. Lowestoft, Suffolk.

1877. *Champernowne, Arthur, M.A., F.G.S. Dartington Hall, Totnes, Devon.

*Champney, Henry Nelson. 4 New-street, York.

1881. *Champney, John E. Woodlands, Halifax.

1865. ‡Chance, A. M. Edgbaston, Birmingham.

1865. *Chance, James T. 51 Prince's-gate, London, S.W.

1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.

1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Frewen Hall, Oxford.

1877. §Chapman, T. Algernon, M.D. Burghill, Hereford.

1866. ‡Chapman, William. The Park, Nottingham.

1871. §Chappell, William, F.S.A. Strafford Lodge, Oatlands Park, Weybridge Station.

1874. ‡Charles, John James, M.A., M.D. 11 Fisherwick-place, Belfast.

1871. ‡*Charles, T. C., M.D. Queen's College, Belfast.*

1836. Charlesworth, Edward, F.G.S. 277 Strand, London, W.C.

1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.

1863. ‡Charlton, Edward, M.D. 7 Eldon-square, Newcastle-on-Tyne.

1866. ‡Charnock, Richard Stephen, Ph.D., F.S.A., F.R.G.S. Junior Garrick Club, Adelphi-terrace, London, W.C.

Chatto, W. J. P. Union Club, Trafalgar-square, London, S.W.

1867. *Chatwood, Samuel, F.R.G.S. Irwell House, Drinkwater Park, Prestwich.

1864. ‡Cheadle, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, S.W.

1874. *Chermside, Lieutenant H. C., R.E. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, London, S.W.

1879. *Chesterman, W. Broomsgrove-road, Sheffield.

1879. ‡Cheyne, Commander J. P., R.N. 1 Westgate-terrace, West Brompton, London, S.W.

1872. §Chichester, The Right Hon. the Earl of. Stanmer House, Lewes.

Chichester, The Right Rev. Richard Durnford, D.D., Lord Bishop of. Chichester.

1865. *Child, Gilbert W., M.A., M.D., F.L.S. Cowley House, Oxford.

1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.

1863. ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.

1859. ‡Christie, John, M.D. 46 School-hill, Aberdeen.

1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.

Christison, Sir Robert, Bart., M.D., D.C.L., F.R.S.E., Professor of Dietetics, Materia Medica, and Pharmacy in the University of Edinburgh. Edinburgh.

1875. *Christopher, George, F.C.S. 8 Rectory-grove, Clapham, London, S.W.

1876. *Chrystal, G., B.A., Professor of Mathematics. 15 Chalmers-street, Edinburgh.

1870. §Church, A. H., M.A., F.C.S., Professor of Chemistry to the Royal Academy of Arts, London. Royston House, Kew, Surrey.

1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.

Year of
Election.

1881. §Churchill, Lord Alfred Spencer, F.R.G.S. 16 Rutland-gate, London, S.W.
1857. ‡Churchill, F., M.D. Ardtrea Rectory, Stewartstown, Co. Tyrone.
1868. ‡Clabburn, W. H. Thorpe, Norwich.
1863. ‡Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.
1869. ‡Clapp, Frederick. 44 Magdalen-street, Exeter.
1857. ‡Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square, Dublin.
1859. ‡Clark, David. Coupar Angus, Fifeshire.
1877. *Clark, F. J. Street, Somerset.
Clark, G. T. 44 Berkeley-square, London, W.
1876. ‡Clark, George W. Glasgow.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1861. ‡Clark, Latimer. 5 Westminster-chambers, Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
Clarke, George. Mosley-street, Manchester.
1872. *Clarke, Hyde. 32 St. George's-square, Pimlico, London, S.W.
1881. §Clarke, J. Edmund, B.A., B.Sc., F.G.S. 20 Bootham, York.
1875. ‡Clarke, John Henry. 4 Worcester-terrace, Clifton, Bristol.
1861. *Clarke, John Hope. Lark Hill House, Edgeley, Stockport.
1877. ‡Clarke, Professor John W. University of Chicago, Illinois.
1851. ‡Clarke, Joshua, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1861. ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1856. *Clay, Colonel William. The Slopes, Wallasea, Cheshire.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1850. ‡Cleghorn, Hugh, M.D., F.L.S. Stravithie, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1861. §Cleland, John, M.D., F.R.S., Professor of Anatomy in the University of Glasgow. 2 College, Glasgow.
1857. ‡*Clements, Henry. Dromin, Listowel, Ireland.*
‡*Clerk, Rev. D. M. Deverill, Warminster, Wiltshire.*
1873. §Cliff, John, F.G.S. Linnburn, Ilkley, near Leeds.
1861. *Clifton, R. Bellamy, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1854. ‡Close, The Very Rev. Francis, M.A., D.D., Dean of Carlisle.
1878. §Close, Rev. Maxwell H., F.G.S. 40 Lower Baggot-street, Dublin.
1866.§§Close, Thomas, F.S.A. St. James's-street, Nottingham.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1859. ‡Clouston, Rev. Charles. Sandwick, Orkney.
1861. *Clouston, Peter. 1 Park-terrace, Glasgow.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1881. *Clutton, William James. The Mount, York.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1855. *Coats, Sir Peter. Woodside, Paisley.
1855. *Coats, Thomas. Fergeslie House, Paisley.
Cobb, Edward. 13 Great Bedford-street, Bath.
1851. *Cobbold, John Chevallier. Holywells, Ipswich; and Athenæum Club, London, S.W.

Year of
Election.

1864. ‡Cobbold, T. Spencer, M.D., F.R.S., F.L.S., Professor of Botany and Helminthology in the Royal Veterinary College, London. 74 Portsdown-road, Maida Hill, London, W.
1864. *Cochrane, James Henry. Lochiar, Cork.
1861. *Coe, Rev. Charles C., F.R.G.S. Highfield, Manchester-road, Bolton.
1881. §Coffin, Walter Harris, F.C.S. 94 Cornwall-gardens, South Kensington, London, S.W.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1876. ‡Colbourn, E. Rushton. 5 Marchmont-terrace, Hillhead, Glasgow.
1853. ‡Colchester, William, F.G.S. Springfield House, Ipswich.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1876. ‡Colebrooke, Sir T. E., Bart., M.P., F.R.G.S. 14 South-street, Park-lane, London, W.; and Abington House, Abington, N.B.
1860. ‡Coleman, J. J., F.C.S. 69 St. George's-place, Glasgow.
1878. ‡Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, London, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1857. ‡Colles, William, M.D. 21 Stephen's-green, Dublin.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1854. ‡Collingwood, Cuthbert, M.A., M.B., F.L.S. 2 Gipsy Hill-villas, Upper Norwood, Surrey, S.E.
1861. *Collingwood, J. Frederick, F.G.S. Anthropological Institute, 4 St. Martin's-place, London, W.C.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. §Collins, J. H., F.G.S. 57 Lemon-street, Truro, Cornwall.
1876. ‡Collins, William. 3 Park-terrace East, Glasgow.
1868. *Colman, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1870. ‡Coltart, Robert. The Hollies, Aigburth-road, Liverpool.
1874. ‡*Combe, James. Ormiston House, Belfast.*
*Compton, The Ven. Lord Alwyn, Dean of Worcester. The Deanery, Worcester.
1846. *Compton, Lord William. 145 Piccadilly, London, W.
1852. ‡Connal, Michael. 16 Lynedock-terrace, Glasgow.
1871. *Connor, Charles C. Hope House, College Park East, Belfast.
1881. §Conroy, Sir John, Bart. Arborfield, Reading, Berks.
1876. ‡Cook, James. 162 North-street, Glasgow.
1876. *Cooke, Conrad W., C.E. 5 Westminster-chambers, London, S.W.
1881. §Cooke, F. Bishophill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
Cooke, James R., M.A. 73 Blessington-street, Dublin.
Cooke, J. B. Cavendish-road, Birkenhead.
1868. ‡Cooke, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
1881. §Cooke, Thomas. Bishophill, York.
1859. *Cooke, William Henry, M.A., Q.C., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1863. ‡Cookson, N. C. Benwell Tower, Newcastle-on-Tyne.
1869. §Cooling, Edwin, F.R.G.S. Mile Ash, Derby.
1850. ‡Cooper, Sir Henry, M.D. 7 Charlotte-street, Hull.
Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1879. §§Cooper, Thomas. Rose Hill, Rotherham, Yorkshire.
1868. ‡Cooper, W. J. The Old Palace, Richmond, Surrey.
1846. ‡Cooper, William White, F.R.C.S. 19 Berkeley-square, London, W.

Year of Election.

1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1868. ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1881. §Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1863. ‡Coppin, John. North Shields.
1842. Corbett, Edward. Ravenoak, Cheadle-hulme, Cheshire.
1855. ‡Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology in Queen's College, Cork.
1881. §Cordeaux, John. Great Cotes, Ulceby, Lincolnshire.
1870. *Corfield, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiène and Public Health in University College. 10 Bolton-row, Mayfair, London, W.
Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. Brazenose-street, Manchester.
1855. ‡Cotterill, Rev. Henry, Bishop of Edinburgh. Edinburgh.
1874. *Cotterill, J. H., M.A., F.R.S., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864. ‡Cotton, General Frederick C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, London, S.W.
1869. ‡Cotton, William. Pennsylvania, Exeter.
1879. §Cottrill, Gilbert I. Shepton Mallett, Somerset.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1874. ‡Courtauld, John M. Bocking Bridge, Braintree, Essex.
1834. ‡Cowan, Charles. 38 West Register-street, Edinburgh.
1876. ‡Cowan, J. B., M.D. Helensburgh, N.B.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William. Comptons Lea, Horsham.
1873. **Cowans, John. Cranford, Middlesex.*
Cowie, The Very Rev. Benjamin Morgan, M.A., B.D., Dean of Manchester. The Deanery, Manchester.
1871. ‡Cowper, C. E. 3 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.I.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. 18 Windsor-street, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1867. ‡Cox, James. Clement Park, Lochee, Dundee.
1870. *Cox, James. 8 Falkner-square, Liverpool.
1867. *Cox, Thomas Hunter. Duncarse, Dundee.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1866. *Cox, William H. 150 Newhall-street, Birmingham.
Craig, J. T. Gibson, F.R.S.E. 24 York-place, Edinburgh.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1857. ‡Crampton, Rev. Josiah. Nettlebeds, near Oxford.
1879. ‡Crampton, Thomas Russell. 13 Victoria-street, London, S.W.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1876. ‡Crawford, Chalmond. Ridemon, Crosscar.
1871. *Crawford and Balcarres, The Right Hon. the Earl of, F.R.S., F.R.A.S. 47 Brook-street, London, W.
1871. *Crawford, William Caldwell, M.A. 27 Ziegelhaüser-strasse, Heidelberg.
1871. ‡Crawshaw, Edward. Burnley, Lancashire.
1870. *Crawshay, Mrs. Robert. Cathedine, Bwlch, Breconshire.
1879. §§Creswick, Nathaniel. Handsworth Grange, near Sheffield.
1876. *Crewdson, Rev. George. St. George's Vicarage, Kendal.

Year of Election.

CREYKE, The Venerable Archdeacon, M.A. Bolton Percy Rectory, Tadcaster.
1880. *Crisp, Frank, B.A., LL.B. 5 Lansdowne-road, Notting Hill, London, W.
1858. ‡Crofts, John. Hillary-place, Leeds.
1878. §Croke, John O'Byrne, M.A. The French College, Blackrock, Dublin.
1859. ‡Croll, A. A. 10 Coleman-street, London, E.C.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1866. ‡*Cronin, William. 4 Brunel-terrace, Nottingham.*
1870. ‡Crookes, Joseph. Marlborough House, Brook Green, Hammersmith, London, W.
1865. §CROOKES, WILLIAM, F.R.S., F.C.S. 7 Kensington Park-gardens, London, W.
1879. ‡Crookes, Mrs. 7 Kensington Park-gardens, London, W.
1855. ‡Cropper, Rev. John. Wareham, Dorsetshire.
1870. ‡Crosfield, C. J. 16 Alexandra-drive, Prince's Park, Liverpool.
1870. ‡Crosfield, William, sen. Annesley, Aigburth, Liverpool.
1870. *Crosfield, William, jun. 16 Alexandra-drive, Prince's Park, Liverpool.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1867. §CROSSKEY, Rev. H. W., F.G.S. 28 George-road, Edgbaston, Birmingham.
1853. ‡Crosskill, William, C.E. Beverley, Yorkshire.
1870. *Crossley, Edward, F.R.A.S. Bemerside, Halifax.
1871. ‡Crossley, Herbert. Broomfield, Halifax.
1866. *Crossley, Louis J., F.M.S. Moorside Observatory, near Halifax.
1861. §Crowley, Henry. Trafalgar-road, Birkdale Park, Southport.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.
1860. ‡Cruickshank, John. Aberdeen.
1859. ‡Cruickshank, Provost. Macduff, Aberdeen.
1873. ‡Crust, Walter. Hall-street, Spalding.
Culley, Robert. Bank of Ireland, Dublin.
1878.§§Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1861. *Cunliffe, Edward Thomas. The Elms, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. The Elms, Handforth, Manchester.
1877. ‡Cunningham, D. J., M.D. University of Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1855. ‡*Cunningham, William A. 2 Broadwalk, Buxton.*
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1866. ‡Cunnington, John. 68 Oakley-square, Bedford New Town, London, N.W.
1881. §Curley, T., C.E., F.G.S. Hereford.
1867. *Cursetjee, Manockjee, F.R.G.S., Judge of Bombay. Villa-Byculla, Bombay.
1857. ‡CURTIS, ARTHUR HILL, LL.D. 1 Hume-street, Dublin.
1878. §Curtis, William. Caramore, Sutton, Co. Dublin.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, London, S.W.

1863. ‡Daglish, John. Hetton, Durham.
1854. ‡Daglish, Robert, C.E. Orrell Cottage, near Wigan.

Year of Election.

1863. ‡Dale, J. B. South Shields.
1853. ‡Dale, Rev. P. Steele, M.A. Hollingfare, Warrington.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W. Dundee.
1870. ‡Dallinger, Rev. W. H., F.R.S. Sheffield College, Glossop-road, Sheffield.
Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
1859. ‡*Dalrymple, Charles Elphinstone. West Hall, Aberdeenshire.*
1859. ‡Dalrymple, Colonel. Troup, Scotland.
Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.
*Dalton, Rev. J. E., B.D. Seagrave, Loughborough.
1862. ‡DANBY, T. W. Downing College, Cambridge.
1859. ‡Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
1876. ‡Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A., F.G.S. 26 George-street, Manchester.
1876. ‡Darling, G. Erskine. 247 West George-street, Glasgow.
DARWIN, CHARLES R., M.A., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E. and M.R.I.A. Down, near Bromley, Kent.
1881. *DARWIN, GEORGE HOWARD, M.A., F.R.S., F.R.A.S. Trinity College, Cambridge.
1878. §Darwin, Horace. 66 Hills-road, Cambridge.
1848. ‡DaSilva, Johnson. Burntwood, Wandsworth Common, London, S.W.
1878. ‡D'Aulmay, G. 22 Upper Leeson-street, Dublin.
1872. ‡Davenport, John T. 64 Marine Parade, Brighton.
1880. §Davey, Henry, C.E., Rupert Lodge, Grove-road, Headingley, Leeds.
1870. ‡Davidson, Alexander, M.D. 8 Peel-street, Toxteth Park, Liverpool.
1871. ‡Davidson, James. Newbattle, Dalkeith, N.B.
1859. ‡Davidson, Patrick. Inchmarlo, near Aberdeen.
1872. ‡DAVIDSON, THOMAS, F.R.S., F.G.S. 3 Leopold-road, Brighton.
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1842. Davies-Colley, Dr. Thomas. Newton, near Chester.
1873. *Davis, Alfred. 5 Westminster-chambers, London, S.W.
1870. *Davis, A. S. 12 Suffolk-square, Cheltenham.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
Davis, Rev. David, B.A. Lancaster.
1881. §Davis, George E. Dagmar Villa, Heaton Chapel, Stockport.
1873. *DAVIS, JAMES W., F.G.S., F.S.A. Chevinedge, near Halifax.
1856. *DAVIS, Sir JOHN FRANCIS, Bart., K.C.B., F.R.S., F.R.G.S. Hollywood, near Compton, Bristol.
1859. *Davis, Richard, F.L.S. 9 St. Helen's-place, London, E.C.
1873. ‡Davis, William Samuel. 1 Cambridge Villas, Derby.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡DAVY, EDMUND W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. M. Bedford-circus, Exeter.
Dawes, John Samuel, F.G.S. Lappel Lodge, Quinton, near Birmingham.
1860. *Dawes, John T., F.G.S. Cefn Mawr Hall, Mold, North Wales.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.G.S., F.S.A., Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
Dawson, John. Barley House, Exeter.

Year of Election.

1855. ‡Dawson, John W., M.A., LL.D., F.R.S., F.G.S., Principal of M'Gill College, Montreal, Canada.
1859. *Dawson, Captain William G. Plumstead Common-road, Kent, S.E.
1879. §Day, Francis. Kenilworth House, Cheltenham.
1871. ‡Day, St. John Vincent, C.E., F.R.S.E. 166 Buchanan-street, Glasgow.
1870. §Deacon, G. F., M.I.C.E. Rock Ferry, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1859. ‡*Dean, David. Banchory, Aberdeen.*
1861. ‡Dean, Henry. Colne, Lancashire.
1870. *Deane, Rev. George, B.A., D.Sc., F.G.S. Spring Hill College, Moseley, near Birmingham.
1866. ‡Debus, Heinrich, Ph.D., F.R.S., F.C.S., Lecturer on Chemistry at Guy's Hospital, London, S.E.
1878. §§Delany, Rev. William. St. Stanislaus College, Tullamore.
1854. *De La Rue, Warren, M.A., D.C.L., Ph.D., F.R.S., F.C.S., F.R.A.S. 73 Portland-place, London, W.
1879. ‡De la Sala, Colonel. Sevilla House, Navarino-road, London, N.W.
1870. ‡De Meschin, Thomas, M.A., LL.D. 4 Hare-court, Temple, London, E.C.
Denchar, John. Morningside, Edinburgh.
1875. ‡Denny, William. Seven Ship-yard, Dumbarton.
Dent, William Yerbury. Royal Arsenal, Woolwich.
1870. *Denton, J. Bailey. 22 Whitehall-place, London, S.W.
1874. §De Rance, Charles E., F.G.S. 28 Jermyn-street, London, S.W.
1856. *Derby, The Right Hon. the Earl of, M.A., LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London, S.W.; and Knowsley, near Liverpool.
1874. *Derham, Walter, M.A., LL.M., F.G.S. Henleaze Park, Westbury-on-Trym, Bristol.
1878. ‡De Rinzy, James Harward. Khelat Survey, Sukkur, India.
1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
De Tabley, George, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.
1869. ‡Devon, The Right Hon. the Earl of, D.C.L. Powderham Castle, near Exeter.
*Devonshire, His Grace the Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.
1868. ‡Dewar, James, M.A., F.R.S., F.R.S.E., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural Experimental Philosophy in the University of Cambridge. 19 Brookside, Cambridge.
1881. §Dewar, Mrs. 19 Brookside, Cambridge.
1872. ‡Dewick, Rev. E. S. 2 Southwick-place, Hyde Park, London, W.
1873. *Dew-Smith, A. G. 7a Eaton-square, London, S.W.
1852. ‡Dickie, George, M.A., M.D., F.R.S., F.L.S., Professor of Botany in the University of Aberdeen.
1864. *Dickinson, F. H., F.G.S. Kingweston, Somerton, Taunton; and 121 St. George's-square, London, S.W.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.
1867. ‡Dickson, Alexander, M.D., Professor of Botany in the University of Edinburgh. 11 Royal-circus, Edinburgh.

Year of
Election.
1881. §Dickson, Edmund. West Cliff, Preston.
1862. *Dilke, Sir Charles Wentworth, Bart., M.P., F.R.G.S. 76 Sloane-street, London, S.W.
1877. §Dillon, James, C.E. 17 Kildare-street, Dublin.
1848. ‡Dillwyn, Lewis Llewelyn, M.P., F.L.S., F.G.S. Parkwerne, near Swansea.
1872. §Dines, George. Woodside, Hersham, Walton-on-Thames.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1859. *Dingle, Rev. J. Lanchester Vicarage, Durham.
1876. ‡Ditchfield, Arthur. 12 Taviton-street, Gordon-square, London, W.C.
1868. ‡Dittmar, W. Andersonian University, Glasgow.
1874. *Dixon, A. E. Dunowen, Cliftonville, Belfast.
1853. ‡Dixon, Edward, M.I.C.E. Wilton House, Southampton.
1879. *Dixon, Harold B., M.A., F.C.S. Trinity College, Oxford.
*Dobbin, Leonard, M.R.I.A. 27 Gardiner's-place, Dublin.
1851. ‡Dobbin, Orlando T., LL.D., M.R.I.A. Ballivor, Kells, Co. Meath.
1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne Park, London, W.
1878. *Dobson, G. E., M.A., M.B., F.L.S. Royal Victoria Hospital, Netley, Southampton.
1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.
1875. *Docwra, George, jun. Grosvenor-road, Handsworth, Birmingham.
1870. *Dodd, John. 6 Thomas-street, Liverpool.
1876. ‡Dodds, J. M. 15 Sandyford-place, Glasgow.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1851. ‡Domvile, William C., F.Z.S. Thorn Hill, Bray, Dublin.
1867. ‡Don, John. The Lodge, Broughty Ferry, by Dundee.
1867. ‡Don, William G. St. Margaret's, Broughty Ferry, by Dundee.
1873. ‡Donham, Thomas. Huddersfield.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *Donkin, Bryan, jun. May's Hill, Shortlands, Kent.
1874. ‡Donnell, Professor, M.A. 76 Stephen's-green South, Dublin.
1861. ‡Donnelly, Colonel, R.E. South Kensington Museum, London, W.
1881. §Dorrington, John Edward. Lypiatt Park, Stroud.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871. ‡Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.
1863. *Doughty, Charles Montagu. Theberton Hall, Saxmundham, Suffolk.
1876. *Douglas, Rev. G. C. M. 10 Fitzroy-place, Glasgow.
1877. *Douglass, James N., C.E. Trinity House, London, E.C.
1878. ‡Douglass, William. 104 Baggot-street, Dublin.
1855. ‡*Dove, Hector. Rose Cottage, Trinity, near Edinburgh.*
1870. ‡Dowie, J. Muir. Wetstones, West Kirby, Cheshire.
1876. §Dowie, Mrs. Muir. Wetstones, West Kirby, Cheshire.
1878. ‡Dowling, Thomas. Claireville House, Terenure, Dublin.
1857. ‡Downing, S., C.E., LL.D., Professor of Civil Engineering in the University of Dublin. 4 The Hill, Monkstown, Co. Dublin.
1878. ‡Dowse, The Right Hon. Baron. 38 Mountjoy-square, Dublin.
1865. *Dowson, E. Theodore. Geldeston, near Beccles, Suffolk.
1881. §Dowson, Joseph Emerson, C.E. 3 Great Queen-street, London, S.W.
1868. ‡Dresser, Henry E., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.
1873.§§Drew, Frederic, F.G.S., F.R.G.S. Eton College, Windsor.
1869. §Drew, Joseph, LL.D., F.R.A.S., F.G.S. Weymouth.
1879. ‡Drew, Joseph, M.B. Foxgrove-road, Beckenham, Kent.
1865. ‡*Drew, Robert A. 6 Stanley-place, Duke-street, Broughton, Manchester.*

Year of Election.

1879. ‡*Drew, Samuel, M.D., D.Sc., F.R.S.E. Chapeltown, Edinburgh.*
1872. *Druce, Frederick. 27 Oriental-place, Brighton.
1874. ‡Druitt, Charles. Hampden-terrace, Rugby-road, Belfast.
1866. *Dry, Thomas. 23 Gloucester-road, Regent's Park, London, N.W.
1870. §Drysdale, J. J., M.D. 36A Rodney-street, Liverpool.
1856. *DUCIE, The Right. Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Holme House, Columbia-road, Oxton, Birkenhead.
1867. *DUFF, The Right Hon. MOUNTSTUART ELPHINSTONE GRANT-, M.P., LL.B., F.R.S., F.R.G.S. York House, Twickenham, Middlesex.
1852. ‡Dufferin and Clandeboye, The Right Hon. the Earl of, K.P., K.C.B., LL.D., F.R.S., F.R.G.S. Clandeboye, near Belfast, Ireland.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange, C.E. Waterford.
1859. *Duncan, Alexander. 7 Prince's-gate, London, S.W.
1859. ‡Duncan, Charles. 52 Union-place, Aberdeen.
1866. *Duncan, James. 71 Cromwell-road, South Kensington, London, W.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1871. ‡Duncan, James Matthew, M.D. 30 Charlotte-square, Edinburgh.
1867. §DUNCAN, PETER MARTIN, M.B., F.R.S., F.G.S., Professor of Geology in King's College, London. 4 St. George's-terrace, Regent's Park-road, London, N.W.
1880. §Duncan, William S. 79 Wolverhampton-road, Stafford.
1881. §Duncombe, The Hon. Cecil. Nawton Grange, York.
1881. §Dunhill, Charles H. Gray's-court, York.
1853. *Dunlop, William Henry. Annanhill, Kilmarnock, Ayrshire.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1876. *Dunn, James. 64 Robertson-street, Glasgow.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. ‡Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1866. ‡Duprey, Perry. Woodbury Down, Stoke Newington, London, N.
1869. ‡D'Urban, W. S. M., F.L.S. 4 Queen-terrace, Mount Radford, Exeter.
1860. ‡DURHAM, ARTHUR EDWARD, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
Dykes, Robert. Kilmorie, Torquay, Devon.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Woburn.

1868. ‡Eade, Peter, M.D. Upper St. Giles's-street, Norwich.
1861. ‡Eadson, Richard. 13 Hyde-road, Manchester.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
*EARNSHAW, Rev. SAMUEL, M.A. 14 Broomfield, Sheffield.
1874. §Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1871. *EASTON, EDWARD, C.E., F.G.S. 11 Delahay-street, Westminster, S.W.
1863. §Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John, C.E. Durie House, Abercromby-street, Helensburgh, N.B.
1870. §Eaton, Richard. Nuttall House, Nuttall, Nottinghamshire.
Ebden, Rev. James Collett, M.A., F.R.A.S. Great Stukeley Vicarage, Huntingdonshire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.

Year of Election.

1858. *Eddison, Francis. Martinstown, Dorchester.
1870. *Eddison, John Edwin, M.D., M.R.C.S. 29 Park-square, Leeds.
*Eddy, James Ray, F.G.S. Carleton Grange, Skipton.
Eden, Thomas. Talbot-road, Oxton.
**Edgeworth, Michael P., F.L.S., F.R.A.S. Mastrim House, Anerley, London, S.E.*
1855. ‡*Edmiston, Robert. Elmbank-crescent, Glasgow.*
1859. ‡Edmond, James. Cardens Haugh, Aberdeen.
1870. *Edmonds, F. B. 72 Portsdown-road, London, W.
1867. *Edward, Allan. Farington Hall, Dundee.
1867. ‡Edward, Charles. Chambers, 8 Bank-street, Dundee.
1855. *EDWARDS, Professor J. BAKER, Ph.D., D.C.L. Montreal, Canada.
1859. *Eisdale, David A., M.A. 38 Dublin-street, Edinburgh.
1873. ‡Elcock, Charles. 39 Lyme-street, Shakspere-street, Ardwick, Manchester.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. St. Mary, Bedford.
Ellacombe, Rev. H. T., F.S.A. Clyst St. George, Topsham, Devon.
1863. ‡Ellenberger, J. L. Worksop.
1880. *Elliot, Colonel Charles, C.B. Muirhead, Davidson's Mains, N.B.
1855. §Elliot, Robert, F.B.S.E. Wolfelee, Hawick, N.B.
1861. *ELLIOT, Sir WALTER, K.C.S.I., F.R.S., F.L.S. Wolfelee, Hawick, N.B.
1864. ‡Elliott, E. B. Washington, United States.
1872. ‡Elliott, Rev. E. B. 11 Sussex-square, Kemp Town, Brighton.
Elliott, John Fogg. Elvet Hill, Durham.
1879. §Elliott, Joseph W. Post Office, Bury, Lancashire.
1864. *ELLIS, ALEXANDER JOHN, B.A., F.R.S., F.S.A. 25 Argyll-road, Kensington, London, W.
1877. ‡Ellis, Arthur Devonshire. School of Mines, Jermyn-street, London, S.W.; and Thurnscoe Hall, Rotherham, Yorkshire.
1875. *Ellis, H. D. 67 Ladbroke Grove-road, Notting Hill, London, W.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1880. §Ellis, J. H. Town Hall, Southport.
1864. ‡Ellis, J. Walter. High House, Thornwaite, Ripley, Yorkshire.
*Ellis, Rev. Robert, A.M. The Institute, St. Saviour's Gate, York.
1869. ‡ELLIS, WILLIAM HORTON. Hartwell House, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1862. ‡Elphinstone, H. W., M.A., F.L.S. Cadogan-place, London, S.W.
1863. ‡Embleton, Dennis, M.D. Northumberland-street, Newcastle-on-Tyne.
1863. ‡Emery, Rev. W., B.D. Corpus Christi College, Cambridge.
1858. ‡Empson, Christopher. Bramhope Hall, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1866. ‡Enfield, William. Low Pavement, Nottingham.
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. ‡English, J. T. Stratton, Cornwall.
ENNISKILLEN, The Right Hon. WILLIAM WILLOUGHBY, Earl of, LL.D., D.C.L., F.R.S., F.G.S., M.R.I.A. 65 Eaton-place, London, S.W.; and Florence Court, Fermanagh, Ireland.
1869. *Enys, John Davis. Care of F. G. Enys, Esq., Enys, Penryn, Cornwall.
1844. ‡Erichsen, John Eric, F.R.S., F.R.C.S., Professor of Clinical Surgery in University College, London. 6 Cavendish-place, London, W.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.

Year of
Election.

1862. *Esson, William, M.A., F.R.S., F.C.S., F.R.A.S. Merton College; and 1 Bradmore-road, Oxford.
1878. ‡Estcourt, Charles, F.C.S. 8 St. James's-square, John Dalton-street, Manchester.
Estcourt, Rev. W. J. B. Long Newton, Tetbury.
1869. ‡Etheridge, Robert, F.R.S.L. & E., F.G.S., Palæontologist to the Geological Survey of Great Britain. Museum of Practical Geology, Jermyn-street; and 19 Halsey-street, Cadogan-place, London, S.W.
1881. §Evans, Alfred. Exeter College, Oxford.
1870. *Evans, Arthur John, F.S.A. Nash Mills, Hemel Hempsted.
1865. *Evans, Rev. Charles, M.A. The Rectory, Solihull, Birmingham.
1876. ‡Evans, Captain Sir Frederick J. O., K.C.B., R.N., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty. 116 Victoria-street, Westminster, S.W.
1869. *Evans, H. Saville W. Wimbledon Park House, Wimbledon, S.W.
1861. *Evans, John, D.C.L., LL.D., V.P.R.S., F.S.A., F.G.S. 65 Old Bailey, London, E.C.; and Nash Mills, Hemel Hempsted.
1881. §Evans, Lewis. Silver Lead Mine, Llanfyrnach, Pembrokeshire.
1876. ‡Evans, Mortimer, C.E. 97 West Regent-street, Glasgow.
1865. ‡Evans, Sebastian, M.A., LL.D. Highgate, near Birmingham.
1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1866. ‡Evans, Thomas, F.G.S. Belper, Derbyshire.
1865. *Evans, William. The Spring, Kenilworth.
1871. §Eve, H. Weston, M.A. University College, London, W.C.
1868. *Everett, J. D., M.A., D.C.L., F.R.S. L. & E., Professor of Natural Philosophy in Queen's College, Belfast. Rushmere, Malone-road, Belfast.
1880. §§Everingham, Edward. St. Helen's-road, Swansea.
1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1881. §Ewart, J. Cossar, M.D., Professor of Natural History in the University of Aberdeen. Aberdeen.
1874. ‡Ewart, William, M.P. Glenmachan, Belfast.
1874. ‡Ewart, W. Quartus. Glenmachan, Belfast.
1859. *Ewing, Archibald Orr, M.P. Ballikinrain Castle, Killearn, Stirlingshire.
1876. *Ewing, James Alfred, B.Sc., F.R.S.E., Professor of Mechanical Engineering in the University of Tokio, Japan. 12 Laurel Bank, Dundee.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1846. *Eyre, George Edward, F.G.S., F.R.G.S. 59 Lowndes-square, London, S.W.; and Warrens, near Lyndhurst, Hants.
1866. ‡Eyre, Major-General Sir Vincent, K.C.S.I., F.R.G.S. Athenæum Club, Pall Mall, London, S.W.
Eyton, Charles. Hendred House, Abingdon.
1849. ‡Eyton, T. C. Eyton, near Wellington, Salop.

1865. ‡Fairley, Thomas, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1876. ‡Fairlie, James M. Charing Cross Corner, Glasgow.
1870. ‡Fairlie, Robert, C.E. Woodlands, Clapham Common, London, S.W.
1878. *Fairlie, Robert F. Palace-chambers, Victoria-street, Westminster, S.W.
1864. ‡Falkner, F. H. Lyncombe, Bath.
1877. §Faraday, F. J., F.S.S. College Chambers, 17 Brazenose-street, Manchester.

Year of Election.

1879. *Farnworth, Ernest. Swindon, near Dudley.
1859. ‡Farquharson, Robert O. Houghton, Aberdeen.
1861. †FARR, WILLIAM, C.B., M.D., D.C.L., F.R.S. 78 Portsdown-road, Maida Hill, London, W.
1866. *FARRAR, Rev. FREDERICK WILLIAM, M.A., D.D., F.R.S., Canon of Westminster. St. Margaret's Rectory, Westminster, S.W.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulding, Joseph. The Grange, Greenhill Park, New Barnet, Herts.
1859. *FAWCETT, The Right Hon. HENRY, M.A., M.P., Professor of Political Economy in the University of Cambridge. 51 The Lawn, South Lambeth-road, London, S.W.; and 8 Trumpington-street, Cambridge.
1863. ‡Fawcus, George. Alma-place, North Shields.
1873. *Fazakerley, Miss. The Castle, Denbigh.
1845. ‡Felkin, William, F.L.S. The Park, Nottingham.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1864. *FELLOWS, FRANK P., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. 9 College-square; and Keswick, near Belfast.
1876. *Fergus, Andrew, M.D. 3 Elmbank-crescent, Glasgow.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1859. ‡Ferguson, John. Cove, Nigg, Inverness.
1871. *Ferguson, John, M.A., Professor of Chemistry in the University of Glasgow.
1867. ‡Ferguson, Robert M., Ph.D., F.R.S.E. 8 Queen-street, Edinburgh.
1857. ‡Ferguson, Sir Samuel, LL.D., Q.C. 20 Great George's-street North, Dublin.
1854. ‡Ferguson, William, F.L.S., F.G.S. Kinmundy, near Mintlaw, Aberdeenshire.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1863. *FERNIE, JOHN. Bonchurch, Isle of Wight.
1862. ‡FERRERS, Rev. NORMAN MACLEOD, M.A., F.R.S. Caius College, Cambridge.
1873. ‡Ferrier, David, M.A., M.D., F.R.S., Professor of Forensic Medicine in King's College. 16 Upper Berkeley-street, London, W.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1869. *FIELD, ROGERS, B.A., C.E. 5 Cannon-row, Westminster, S.W.
1876. ‡*Fielden, James. 2 Darnley-street, Pollokshields, near Glasgow.*
Finch, John. Bridge Work, Chepstow.
Finch, John, jun. Bridge Work, Chepstow.
1878. *Findlater, William. 2 Fitzwilliam-square, Dublin.
1881. §Firth, Lieut.-Colonel Sir Charles. Heckmondwike.
1868. ‡Firth, G. W. W. St. Giles's-street, Norwich.
Firth, Thomas. Northwick.
1863. *Firth, William. Burley Wood, near Leeds.
1851. *FISCHER, WILLIAM L. F., M.A., LL.D., F.R.S. St. Andrews, Scotland.
1858. ‡Fishbourne, Admiral E. G., R.N. 26 Hogarth-road, Earl's Court-road, London, S.W.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlston Rectory, near Cambridge.
1873. §Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1879. ‡Fisher, William. Norton Grange, near Sheffield.
1875. *Fisher, W. W., M.A., F.C.S. 2 Park-crescent, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.

Year of Election.

1871. *Fison, Frederick W., F.C.S. Eastmoor, Ilkley, Yorkshire.
1871. ‡Fitch, J. G., M.A. 5 Lancaster-terrace, Regent's Park, London, N.W.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §Fitzgerald, George Francis, M.A. Trinity College, Dublin.
1857. ‡Fitzgerald, The Right Hon. Lord Otho. 13 Dominick-street, Dublin.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Baggot-street, Dublin.
1881. §Fitzsimmons, Henry, M.D. Minster-yard, York.
1865. ‡Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.
Fleetwood, Sir Peter Hesketh, Bart. Rossall Hall, Fleetwood, Lancashire.
1850. ‡Fleming, Professor Alexander, M.D. 121 Hagley-road, Birmingham.
Fleming, Christopher, M.D. Merrion-square North, Dublin.
1881. §Fleming, Rev. Canon James, B.D. The Residence, York.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, near Glasgow.
1876. ‡Fleming, Sandford. Ottawa, Canada.
1867. §Fletcher, Alfred E. 5 Edge-lane, Liverpool.
1870. ‡Fletcher, B. Edgington. Norwich.
1869. ‡Fletcher, Lavington E., C.E. 41 Corporation-street, Manchester.
Fletcher, T. B. E., M.D. 7 Waterloo-street, Birmingham.
1862. ‡Flower, William Henry, LL.D., F.R.S., F.L.S., F.G.S., F.R.C.S., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons. Royal College of Surgeons, Lincoln's-Inn-fields, London, W.C.
1877. *Floyer, Ernest A., F.R.G.S., F.L.S. 7 The Terrace, Putney, S.W.
1881. §Foljambe, Cecil G. S., M.P. 2 Carlton House-terrace, Pall Mall, London, S.W.
1879. ‡Foote, Charles Newth, M.D. 3 Albion-place, Sunderland.
1879. §Foote, Harry D'Oyley, M.D. Rotherham, Yorkshire.
1880. §Foote, R. Bruce. Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.
1873. *Forbes, Professor George, M.A., F.R.S.E. 4 Coates-crescent, Edinburgh.
1877. §Forbes, W. A., B.A. West Wickham, Kent.
Ford, H. R. Morecombe Lodge, Yealand Conyers, Lancashire.
1866. ‡Ford, William. Hartsdown Villa, Kensington Park-gardens East, London, W.
1875. *Fordham, H. George, F.G.S. Odsey Grange, Royston, Herts.
*Forrest, William Hutton. 1 Pitt-terrace, Stirling.
1867. ‡Forster, Anthony. Finlay House, St. Leonard's-on-Sea.
1858. *Forster, The Right Hon. William Edward, M.P., F.R.S. 80 Eccleston-square, London, S.W.; and Wharfeside, Burley-in-Wharfedale, Leeds.
1854. *Fort, Richard. Read Hall, Whalley, Lancashire.
1877. ‡Fortescue, The Right Hon. the Earl. Castle Hill, North Devon.
1870. ‡Forwood, William B. Hopeton House, Seaforth, Liverpool
1875. ‡Foster, A. Le Neve. East Hill, Wandsworth, Surrey, S.W.
1865. ‡Foster, Balthazar, M.D., Professor of Medicine in Queen's College, Birmingham. 16 Temple-row, Birmingham.
1865. *Foster, Clement Le Neve, B.A., D.Sc., F.G.S. Llandudno.
1857. *Foster, George Carey, B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 12 Hilldrop-road, London, N.
*Foster, Rev. John, M.A. 19 Queen's-square, Bath.
1881. §Foster, J. L. Ogleforth, York.

Year of
Election.

1845. ‡Foster, John N. Sandy Place, Sandy, Bedfordshire.
1877. §Foster, Joseph B. 6 James-street, Plymouth.
1859. *FOSTER, MICHAEL, M.A., M.D., Sec. R.S., F.L.S., F.C.S. Trinity College, and Great Shelford, near Cambridge.
1873. ‡*Foster, Peter Le Neve.*
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1859. **Foster, S. Lloyd. Brundall Lodge, Ealing, Middlesex, W.*
1873. *Foster, William. Harrowins House, Queensbury, Yorkshire.
1870. ‡*Foulger, Edward. 55 Kirkdale-road, Liverpool.*
1866. ‡Fowler, George, M.I.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1876. *Fowler, John. 4 Kelvin Bank-terrace, Glasgow.
1870. *Fowler, Robert Nicholas, M.A., M.P., F.R.G.S. 50 Cornhill, London, E.C.
1860. *Fox, Rev. Edward, M.A. Upper Heyford, Banbury.
1876. ‡Fox, St. G. Lane. 9 Sussex-place, London, S.W.
*Fox, Joseph Hayland. The Cleve, Wellington, Somerset.
1860. ‡Fox, Joseph John. Church-row, Stoke Newington, London, N.
1881. *Foxwell, Herbert S., M.A., Professor of Political Economy in University College, London. St. John's College, Cambridge.
1866. *Francis, G. B. Inglesby House, Stoke Newington-green, London, N.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and Manor House, Richmond, Surrey.
1846. ‡FRANKLAND, EDWARD, D.C.L., Ph.D., F.R.S., F.C.S., Professor of Chemistry in the Royal School of Mines. The Yews, Reigate Hill, Surrey.
*Frankland, Rev. Marmaduke Charles. Chowbent, near Manchester.
1859. ‡Fraser, George B. 3 Airlie-place, Dundee.
Fraser, James. 25 Westland-row, Dublin.
Fraser, James William. 8A Kensington Palace-gardens, London, W.
1865. *FRASER, JOHN, M.A., M.D. Chapel Ash, Wolverhampton.
1871. ‡FRASER, THOMAS R., M.D., F.R.S. L. & E. 3 Grosvenor-street, Edinburgh.
1859. *Frazer, Daniel. 113 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1860. ‡Freeborn, Richard Fernandez. 38 Broad-street, Oxford.
1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester, Sussex.
1877. §Freeman, Francis Ford. Black Friars House, Plymouth.
1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
1880. §§Freeman, Thomas. Brynhyfryd, Swansea.
Frere, George Edward, F.R.S. Roydon Hall, Diss, Norfolk.
1869. ‡FRERE, The Right Hon. Sir H. BARTLE E., Bart., G.C.S.I., G.C.B., F.R.S., F.R.G.S. 42 Duke-street, Grosvenor-square, London, W.
1869. ‡Frere, Rev. William Edward. The Rectory, Bilton, near Bristol.
1841. Freeth, Major-General S. 30 Royal-crescent, Notting Hill, London, W.
1857. *Frith, Richard Hastings, C.E., M.R.I.A., F.R.G.S.I. 48 Summer-hill, Dublin.
1869. ‡Frodsham, Charles. 26 Upper Bedford-place, Russell-square, London, W.C.
1847. ‡Frost, William. Wentworth Lodge, Upper Tulse Hill, London, S.W.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
Fry, Francis. Cotham, Bristol.
1875. *Fry, Joseph Storrs. 2 Charlotte-street, Bristol.
1872. *Fuller, Rev. A. Pallant, Chichester.

Year of Election.

1859. ‡FULLER, FREDERICK, M.A., Professor of Mathematics in the University and King's College, Aberdeen.
1869. ‡FULLER, GEORGE, C.E., Professor of Engineering in Queen's College, Belfast. 6 College-gardens, Belfast.
1864. *Furneaux, Rev. Alan. St. German's Parsonage, Cornwall.

1881. §Gabb, Rev. James, M.A. Bulmer Rectory, Welburn, Yorkshire.
*Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡GAGES, ALPHONSE, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Richmond Hill, Sheffield.
1876. ‡Gairdner, Charles. Broom, Newton Mearns, Renfrewshire.
1850. ‡Gairdner, Professor W. T., M.D. 225 St. Vincent-street, Glasgow.
1861. ‡Galbraith, Andrew. Glasgow.
GALBRAITH, Rev. J. A., M.A., M.R.I.A. Trinity College, Dublin.
1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 338 Oxford-street, London, W.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
1875. ‡GALLOWAY, W., H.M. Inspector of Mines. Cardiff.
1860. *GALTON, Captain DOUGLAS, C.B., D.C.L., F.R.S., F.L.S., F.G.S., F.R.G.S. (GENERAL SECRETARY.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *GALTON, FRANCIS, M.A., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. 40 Great Marlborough-street, London, W.
1870. ‡Gamble, J. C. St. Helen's, Lancashire.
1872. *Gamble, John G., M.A. Capetown. (Care of Messrs. Ollivier and Brown, 37 Sackville-street, Piccadilly, London. W.)
1870. §Gamble, Lieut.-Colonel D. St. Helen's, Lancashire.
1877. ‡Gamble, William. St. Helen's, Lancashire.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S., F.R.S.E., Professor of Physiology in Owens College, Manchester. Fairview, Princes-road, Fallowfield, Manchester.
1862. ‡GARNER, ROBERT, F.L.S. Stoke-upon-Trent.
1865. ‡Garner, Mrs. Robert. Stoke-upon-Trent.
1842. Garnett, Jeremiah. Warren-street, Manchester.
1873. ‡Garnham, John. 123 Bunhill-row, London, E.C.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Clayton Lodge, Aigburth, Liverpool.
1842. Gaskell, Rev. William, M.A. Plymouth-grove, Manchester.
1847. *Gaskell, Samuel. Windham Club, St. James's-square, London, S.W.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Park, East Grinstead, Sussex.
1875. §§Gavey, J. 43 Stacey-road, Routh, Cardiff.
1875. ‡Gaye, Henry S. Newton Abbott, Devon.
1873. ‡*Geach, R. G. Cragg Wood, Rawdon, Yorkshire.*
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1859. ‡Geddes, William D., M.A., Professor of Greek in King's College, Old Aberdeen.
1854. ‡Gee, Robert, M.D. 5 Abercromby-square, Liverpool.
1867. ‡GEIKIE, ARCHIBALD, LL.D., F.R.S. L. & E., F.G.S., Director General of the Geological Survey of the United Kingdom. Geological Survey Office, Jermyn-street, London, S.W.
1871. §Geikie, James, F.R.S. L. & E., F.G.S. Balbraith, Perth.

Year of Election.

1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1870. ‡Gerstl, R., F.C.S. University College, London, W.C.
1870. *Gervis, Walter S., M.D., F.G.S. Ashburton, Devonshire.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1871. ‡*Gibson, Alexander.* 10 *Albany-street, Edinburgh.*
1874. ‡Gibson, The Right Hon. Edward, Q.C., M.P. 23 Fitzwilliam-square, Dublin.
1876. *Gibson, George Alexander, M.B., D.Sc., F.G.S. 1 Randolph Cliff, Edinburgh.
*Gibson, George Stacey. Saffron Walden, Essex.
1870. ‡Gibson, Thomas. 51 Oxford-street, Liverpool.
1870. ‡Gibson, Thomas, jun. 10 Parkfield-road, Prince's Park, Liverpool.
1842. GILBERT, JOSEPH HENRY, Ph.D., F.R.S., F.C.S. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1859. *Gilchrist, James, M.D. Crichton House, Dumfries.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
1878. §Giles, Oliver. 16 Bellevue-crescent, Clifton, Bristol.
Giles, Rev. William. Netherleigh House, near Chester.
1878. ‡Gill, Rev. A. W. H. 44 Eaton-square, London, S.W.
1871. *GILL, DAVID. The Observatory, Cape Town.
1881. §Gill, H. C. Bootham, York.
1868. ‡Gill, Joseph. Palermo, Sicily. (Care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.)
1864. ‡GILL, THOMAS. 4 Sydney-place, Bath.
1861. *Gilroy, George. Hindley Hall, Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1876. §Gimingham, Charles H. 45 St. Augustine's-road, Camden-square, London, N.W.
1867. §GINSBURG, Rev. C. D., D.C.L., LL.D. Holmlea, Virginia Water Station, Chertsey.
1869. ‡Girdlestone, Rev. Canon E., M.A. Halberton Vicarage, Tiverton.
1874. *Girdwood, James Kennedy. Old Park, Belfast.
1850. *Gladstone, George, F.C.S., F.R.G.S. 31 Ventnor-villas, Cliftonville, Brighton.
1849. *GLADSTONE, JOHN HALL, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, Hyde Park, London, W.
1875. *Glaisher, Ernest Henry. 1 Dartmouth-place, Blackheath, London, S.E.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, London, S.E.
1871. *GLAISHER, J. W. L., M.A., F.R.S., F.R.A.S. Trinity College, Cambridge.
1881. *GLAZEBROOK, R. T., M.A. Trinity College, Cambridge.
1881. §Gleadow, Frederic. 13 Park-square, Leeds.
1870. §Glen, David Corse, F.G.S. 14 Annfield-place, Glasgow.
1859. ‡*Glennie, J. S. Stuart.* 6 *Stone-buildings, Lincoln's Inn, London, W.C.*
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1874. ‡Glover, George T. 30 Donegall-place, Belfast.
1874. ‡Glover, Thomas. 77 Claverton-street, London, S.W.
1870. ‡Glynn, Thomas R. 1 Rodney-street, Liverpool.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1878. *Godlee, J. Lister. 3 New-square, Lincoln's Inn, London, W.C.
1880. §Godman, F. D. 10 Chandos-street, Cavendish-square, London, W.

Year of Election.

1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. §Godwin-Austen, Lieut.-Colonel H. H., F.R.S., F.Z.S. Deepdale, Reigate.
1846. ‡Godwin-Austen, Robert A. C., B.A., F.R.S., F.G.S. Shalford House, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1877. ‡Goff, James. 11 Northumberland-road, Dublin.
1881. §Goldschmidt, Edward. Nottingham.
1873. ‡Goldthorp, Miss R. F. C Cleckheaton, Bradford, Yorkshire.
1878. ‡Good, Rev. Thomas, B.D. 51 Wellington-road, Dublin.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1870. ‡*Goodison, George William, C.E. Gateacre, Liverpool.*
1842. *Goodman, John, M.D. 8 Leicester-street, Southport.
1865. ‡Goodman, J. D. Minories, Birmingham.
1869. ‡Goodman, Neville. Peterhouse, Cambridge.
1870. *Goodwin, Rev. Henry Albert, M.A., F.R.A.S. Lambourne Rectory, Romford.
1871. *Gordon, Joseph Gordon, F.C.S. 20 King-street, St. James's, London, S.W.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1865. ‡Gore, George, LL.D., F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1870. ‡Gossage, William. Winwood, Woolton, Liverpool.
1875. *Gotch, Francis. Stokes Croft, Bristol.
*Gotch, Rev. Frederick William, LL.D. Stokes Croft, Bristol.
*Gotch, Thomas Henry. Kettering.
1873. §Gott, Charles, M.I.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, The Right Hon. George S., Viscount, M.A., F.L.S., F.G.S. St. Helen's, Booterstown, Dublin.
1881. §Gough, Thomas, B.Sc., F.C.S. Elmfield College, York.
1868. ‡Gould, Rev. George. Unthank-road, Norwich.
1873. ‡Gourlay, J. McMillan. 21 St. Andrew's-place, Bradford, Yorkshire.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. §Gow, Robert. Cairndowan, Dowanhill, Glasgow.
Gowland, James. London-wall, London, E.C.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1861. ‡Grafton, Frederick W. Park-road, Whalley Range, Manchester.
1867. *Graham, Cyril, F.L.S., F.R.G.S. Colonial Office, London, S.W.
1875. ‡Grahame, James. Auldhouse, Pollokshaws, near Glasgow.
1852. *Grainger, Rev. Canon John, D.D., M.R.I.A. Skerry and Rathcavan Rectory, Broughshane, near Ballymena, Co. Antrim.
1871. ‡Grant, Sir Alexander, Bart., M.A., Principal of the University of Edinburgh. 21 Lansdowne-crescent, Edinburgh.
1859. ‡*Grant, Hon. James. Cluny Cottage, Forres.*
1870. ‡Grant, Colonel James A., C.B., C.S.I., F.R.S., F.L.S., F.R.G.S. 19 Upper Grosvenor-street, London, W.
1855. *Grant, Robert, M.A., LL.D., F.R.S., F.R.A.S., Regius Professor of Astronomy in the University of Glasgow. The Observatory, Glasgow.
1854 ‡Grantham, Richard B., C.E., F.G.S. 22 Whitehall-place, London, S.W.
1864. ‡Grantham, Richard F. 22 Whitehall-place, London, S.W.
1881. §Graves, E. 126 King Henry's-road, London, N.W.

Year of Election.

1874. ‡Graves, Rev. James, B.A., M.R.I.A. Inisnag Glebe, Stonyford, Co. Kilkenny.
1881. §Gray, Alan, LL.B. Minster-yard, York.
1864. *Gray, Rev. Charles. The Vicarage, Blyth, Worksop.
1865. ‡Gray, Charles. Swan-bank, Bilston.
1870. ‡Gray, C. B. 5 Rumford-place, Liverpool.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. §Gray, Edwin, LL.B. Minster-yard, York.
1864. ‡Gray, Jonathan. Summerhill House, Bath.
1859. ‡Gray, Rev. J. H. Bolsover Castle, Derbyshire.
1870. ‡Gray, J. Macfarlane. 127 Queen's-road, Peckham, London, S.E.
1878. §Gray, Matthew Hamilton. 14 St. John's Park, Blackheath, London, S.E.
1878. §Gray, Robert Kaye. 14 St. John's Park, Blackheath, London, S.E.
1881. §Gray, Thomas. 21 Haybrom-crescent, Glasgow.
1873. ‡Gray, William, M.R.I.A. 6 Mount Charles, Belfast.
*Gray, Colonel William. Farley Hall, near Reading.
1854. *Grazebrook, Henry. Clent Grove, near Stourbridge, Worcestershire.
1866. §Greaves, Charles Augustus, M.B., LL.B. 101 Friar-gate, Derby.
1873. ‡*Greaves, James H., C.E. Albert-buildings, Queen Victoria-street, London, E.C.*
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 3 South-square, Gray's Inn, London, W.C.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1879. ‡Green, A. F. Leeds.
1858. *Greenhalgh, Thomas. Thornydikes, Sharples, near Bolton-le-Moors.
1881. §Greenhough, Edward. Matlock Bath, Derbyshire.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1875. ‡Greenwood, Frederick. School of Medicine, Leeds.
1862. *Greenwood, Henry. 32 Castle-street, and the Woodlands, Anfield-road, Anfield, Liverpool.
1877. ‡Greenwood, Holmes. 78 King-street, Accrington.
1849. ‡Greenwood, William. Stones, Todmorden.
1861. *Greg, Robert Philips, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1833. Gregg, T. H. 22 Ironmonger-lane, Cheapside, London, E.C.
1860. ‡Gregor, Rev. Walter, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Charles Hutton, C.E. 1 Delahay-street, Westminster, S.W.
1861. §Gregson, Samuel Leigh. Aigburth-road, Liverpool.
1881. §Gregson, William. Baldersby, Thirsk.
1875. ‡Grenfell, J. Granville, B.A., F.G.S. 5 Albert-villas, Clifton, Bristol.
1869. ‡Grey, Sir George, F.R.G.S. Belgrave-mansions, Grosvenor-gardens, London, S.W.
1875. ‡Grey, Mrs. Maria G. 18 Cadogan-place, London, S.W.
1871. *Grierson, Samuel, Medical Superintendent of the District Asylum, Melrose, N.B.
1859. ‡Grierson, Thomas Boyle, M.D. Thornhill, Dumfriesshire.
1875. §Grieve, David, F.R.S.E., F.G.S. Seafield House, Anstruther, Fifeshire.
1870. ‡*Grieve, John, M.D. 21 Lynedock-street, Glasgow.*
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
1859. *Griffith, George, M.A., F.C.S. Harrow.
Griffith, George R. Fitzwilliam-place, Dublin.
1870. §Griffith, Rev. Henry, F.G.S. Barnet, Herts.

Year of Election.

1868. ‡*Griffith, Rev. John, M.A., D.C.L. Findon Rectory, Worthing, Sussex.*
1870. ‡*Griffith, N. R. The Coppa, Mold, North Wales.*
1847. ‡Griffith, Thomas. Bradford-street, Birmingham.
GRIFFITHS, Rev. JOHN, M.A. Wadham College, Oxford.
1879. §Griffiths, Thomas, F.C.S., F.S.S. Silverdale, Oxton, Birkenhead.
1875. ‡Grignon, James, H.M. Consul at Riga. Riga.
1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1842. Grimshaw, Samuel, M.A. Errwod, Buxton.
1881. §Gripper, Edward. Nottingham.
1864. ‡GROOM-NAPIER, CHARLES OTTLEY, F.G.S. 18 Elgin-road, St. Peter's Park, London, N.W.
1869. §Grote, Arthur, F.L.S., F.G.S. 20 Cork-street, Burlington-gardens, London, W.
GROVE, The Hon. Sir WILLIAM ROBERT, Knt., M.A., D.C.L., F.R.S. 115 Harley-street, London, W.
1863. *GROVES, THOMAS B., F.C.S. 80 St. Mary-street, Weymouth.
1869. ‡GRUBB, HOWARD, F.R.A.S. 40 Leinster-square, Rathmines, Dublin.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1856. *GUISE, Lieut.-Colonel Sir WILLIAM VERNON, Bart., F.G.S., F.L.S. Elmore Court, near Gloucester.
1862. ‡Gunn, John, M.A., F.G.S. Irstedd Rectory, Norwich.
1877. ‡Gunn, William, F.G.S. Barnard Castle, Darlington.
1866. ‡GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., Keeper of the Zoological Collections in the British Museum. British Museum, London, W.C.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1868. *Gurney, John. Sprouston Hall, Norwich.
1860. *GURNEY, SAMUEL, F.L.S., F.R.G.S. 20 Hanover-terrace, Regent's Park, London, N.W.
*Gutch, John James. Holgate Lodge, York.
1876. ‡Guthrie, Francis. Cape Town, Cape of Good Hope.
1859. ‡GUTHRIE, FREDERICK, B.A., F.R.S. L. & E., Professor of Physics in the Royal School of Mines. Science Schools, South Kensington, London, S.W.
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1876. ‡Gwyther, R. F. Owens College, Manchester.

1865. ‡Hackney, William. 9 Victoria-chambers, Victoria-street, London, S.W.
1866. *Hadden, Frederick J. South Cliff, Scarborough.
1881. §HADDON, ALFRED CORT, B.A., F.Z.S., Professor of Zoology in the Royal College of Science, Dublin.
1866. ‡*Haddon, Henry. Lenton Field, Nottingham.*
Haden, G. N. Trowbridge, Wiltshire.
1842. Hadfield, George. Victoria-park, Manchester.
1870. ‡Hadivan, Isaac. 3 Huskisson-street, Liverpool.
1848. ‡Hadland, William Jenkins. Banbury, Oxfordshire.
1870. ‡Haigh, George. Waterloo, Liverpool.
*Hailstone, Edward, F.S.A. Walton Hall, Wakefield, Yorkshire.
1879.§§Hake, H. Wilson, Ph.D., F.C.S. Queenswood College, Hants.
1869. ‡Hake, R. C. Grasmere Lodge, Addison-road, Kensington, London, W.
1875. ‡Hale, Rev. Edward, M.A., F.G.S., F.R.G.S. Eton College, Windsor.
1870. ‡Halhead, W. B. 7 Parkfield-road, Liverpool.

Year of Election.

HALIFAX, The Right Hon. Viscount. 10 Belgrave-square, London, S.W.; and Hickleston Hall, Doncaster.
1872. ‡Hall, Dr. Alfred. 30 Old Steine, Brighton.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1881. §Hall, Frederick Thomas, F.R.A.S. Dancershill House, near Barnet, Herts.
1854. *HALL, HUGH FERGIE, F.G.S. Greenheys, Wallasey, Birkenhead.
1859. ‡Hall, John Frederic. Ellerker House, Richmond, Surrey.
1872. *Hall, Captain Marshall. 13 Old-square, Lincoln's Inn, London, W.C.
*Hall, Thomas B. Australia. (Care of J. P. Hall, Esq., Crane House, Great Yarmouth.)
1866. *HALL, TOWNSHEND M., F.G.S. Pilton, Barnstaple.
1860. ‡Hall, Walter. 11 Pier-road, Erith.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1868. *HALLETT, WILLIAM HENRY, F.L.S. Buckingham House, Marine Parade, Brighton.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. The Leys, Barrow-on-Soar, near Loughborough.
1866. ‡HAMILTON, ARCHIBALD, F.G.S. South Barrow, Bromley, Kent.
1869. §Hamilton, Rowland. Oriental Club, Hanover-square, London, W.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1881. *Hammond, Robert. 110 Cannon-street, London, E.C.
1878. ‡Hanagan, Anthony. Luckington, Dalkey.
1878. §Hance, Edward M., LL.B. 103 Hartington-road, Sefton Park, Liverpool.
1875. ‡Hancock, C. F., M.A. 36 Blandford-square, London, N.W.
1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
1850. ‡Hancock, John, J.P. The Manor House, Lurgan, Co. Armagh.
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, London, N.
1857. ‡Hancock, William J. 23 Synnot-place, Dublin.
1847. ‡HANCOCK, W. NEILSON, LL.D., M.R.I.A. 64 Upper Gardiner-street, Dublin.
1876. ‡Hancock, Mrs. W. Neilson. 64 Upper Gardiner-street, Dublin.
1865. ‡Hands, M. Coventry.
1867. ‡Hannah, Rev. John, D.C.L. The Vicarage, Brighton.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1853. ‡Hansell, Thomas T. 2 Charlotte-street, Sculcoates, Hull.
*HARCOURT, A. G. VERNON, M.A., F.R.S., F.C.S. Cowley Grange, Oxford.
Harcourt, Egerton V. Vernon, M.A., F.G.S. Whitwell Hall, Yorkshire.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Millbrooke House, Exeter.
1877. §Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1874. ‡Hardman, E. T., F.C.S. 14 Hume-street, Dublin.
1872. ‡Hardwicke, Mrs. 192 Piccadilly, London, W.
1880. §Hardy, John. 118 Embden-street, Manchester.
*HARE, CHARLES JOHN, M.D., Professor of Clinical Medicine in University College, London. Berkeley House, 15 Manchester-square, London, W.
1858. ‡Hargrave, James. Burley, near Leeds.
1881. §Hargrove, William Wallace. St. Mary's, Bootham, York.
1876. ‡Harker, Allen. 17 Southgate-street, Gloucester.
1878. *Harkness, H. W. Sacramento, California.

Year of Election.

1871. §Harkness, William. Laboratory, Somerset House, London, W.C.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. Brompton, Wykeham Station, York.
1862. *HARLEY, GEORGE, M.D., F.R.S., F.C.S. 25 Harley-street, London, W.
*Harley, John. Ross Hall, near Shrewsbury.
1862. *HARLEY, Rev. ROBERT, F.R.S., F.R.A.S. Mill Hill School, Middlesex; and Burton Bank, Mill Hill, Middlesex, N.W.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *Harmer, Sidney F., B.Sc. King's College, Cambridge.
1872. ‡Harpley, Rev. William, M.A., F.C.P.S. Clayhanger Rectory, Tiverton.
*Harris, Alfred. Lunefield, Kirkby-Lonsdale, Westmoreland.
1871. ‡HARRIS, GEORGE, F.S.A. Iselipps Manor, Northolt, Southall, Middlesex.
1863. ‡Harris, T. W. Grange, Middlesbrough-on-Tees.
1873. ‡*Harris, W. W. Oak-villas, Bradford, Yorkshire.*
1860. ‡Harrison, Rev. Francis, M.A. Oriel College, Oxford.
1864. ‡Harrison, George. Barnsley, Yorkshire.
1873. ‡Harrison, George, Ph.D., F.L.S., F.C.S. 14 St. James's-row, Sheffield.
1874. ‡Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.
1858. *HARRISON, JAMES PARK, M.A. 22 Connaught-street, Hyde Park, London, W.
1870. ‡HARRISON, REGINALD. 51 Rodney-street, Liverpool.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1863. ‡Harrison, T. E. Engineers' Office, Central Station, Newcastle-on-Tyne.
1849. ‡HARROWBY, The Right Hon. DUDLEY RYDER, Earl of, K.G., D.C.L., F.R.S., F.R.G.S. 39 Grosvenor-square, London, W.; and Sandon Hall, Lichfield.
1876. *Hart, Thomas. Bank View, 33 Preston New-road, Blackburn.
1881. §Hart, Thomas. 11 Richmond-terrace, Blackburn.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
Hartley, James. Sunderland.
1871. ‡Hartley, Walter Noel, F.C.S., Professor of Chemistry in the Royal College of Science, Dublin.
1854. §§HARTNUP, JOHN, F.R.A.S. Liverpool Observatory, Bidston, Birkenhead.
1870. ‡Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.
*Harvey, Joseph Charles. Knockrea, Douglas-road, Cork.
Harvey, J. R., M.D. St. Patrick's-place, Cork.
1878. ‡Harvey, R. J., M.D. 7 Upper Merrion-street, Dublin.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-Moors.
1875. ‡HASTINGS, G. W., M.P. Barnard's Green House, Malvern.
Hastings, Rev. H. S. Martley Rectory, Worcester.
1837. ‡*Hastings, W. Huddersfield.*
1857. ‡HAUGHTON, Rev. SAMUEL, M.A., M.D., D.C.L., F.R.S., M.R.I.A., F.G.S., Senior Fellow of Trinity College, Dublin. Dublin.
1874. ‡Hawkins, B. Waterhouse, F.G.S. Century Club, East Fifteenth-street, New York.
1872. *Hawkshaw, Henry Paul. 20 King-street, St. James's, London, S.W.
*HAWKSHAW, Sir JOHN, C.E., F.R.S., F.G.S., F.R.G.S. Hollycombe, Liphook, Petersfield; and 33 Great George-street, London, S.W.

Year of Election.

1864. *Hawkshaw, John Clarke, M.A., F.G.S. 25 Cornwall-gardens, South Kensington, S.W.; and 33 Great George-street, London, S.W.
1868. ‡Hawksley, Thomas, C.E., F.R.S., F.G.S. 30 Great George-street, London, S.W.
1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1859. ‡Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.
1877. ‡Hay, Arthur J. Lerwick, Shetland.
1861. *Hay, Rear-Admiral the Right Hon. Sir John C. D., Bart., C.B., M.P., D.C.L., F.R.S. 108 St. George's-square, London, S.W.
1858. ‡Hay, Samuel. Albion-place, Leeds.
1867. ‡Hay, William. 21 Magdalen-yard-road, Dundee.
1857. ‡Hayden, Thomas, M.D. 30 Harcourt-street, Dublin.
1873. *Hayes, Rev. William A., M.A. 3 Mountjoy-place, Dublin.
1869. ‡Hayward, J. High-street, Exeter.
1858. *Hayward, Robert Baldwin, M.A., F.R.S. The Park, Harrow.
1879. *Hazlehurst, George S. The Elms, Runcorn.
1851. §Head, Jeremiah, C.E., F.C.S. Middlesbrough, Yorkshire.
1869. ‡Head, R. T. The Briars, Alphington, Exeter.
1869. ‡Head, W. R. Bedford-circus, Exeter.
1863. ‡Heald, Joseph. 22 Leazes-terrace, Newcastle-on-Tyne.
1871. §Healey, George. Matson's, Windermere.
1861. *Heape, Benjamin. Northwood, Prestwich, near Manchester.
1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1865. ‡Hearder, William. Rocombe, Torquay.
1877. ‡Hearder, William Keep, F.S.A. 195 Union-street, Plymouth.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
1861. §Heathfield, W. E., F.C.S., F.R.G.S., F.R.S.E. 20 King-street, St. James's, London, S.W.
1865. ‡Heaton, Harry. Harborne House, Harborne, near Birmingham.
1833. ‡Heaviside, Rev. Canon J. W. L., M.A. The Close, Norwich.
1855. ‡Hector, James, M.D., F.R.S., F.G.S., F.R.G.S., Geological Survey of New Zealand. Wellington, New Zealand.
1867. ‡Heddle, M. Foster, M.D., Professor of Chemistry in the University of St. Andrews, N.B.
1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.
1857. *Hemans, George William, C.E., M.R.I.A., F.G.S. 1 Westminster-chambers, Victoria-street, London, S.W.
1867. ‡Henderson, Alexander. Dundee.
1845. ‡Henderson, Andrew. 120 Gloucester-place, Portman-square, London, W.
1873. *Henderson, A. L. 49 King William-street, London, E.C.
1874. ‡Henderson, James Alexander. Norwood Tower, Belfast.
1876. *Henderson, William. Williamfield, Irvine, N.B.
1873. *Henderson, W. D. 9 University-square, Belfast.
1880. *Henderson, Commander W. H., R.N. H.M.S. *Nelson*, Australia.
1856. ‡Hennessy, Henry G., F.R.S., M.R.I.A., Professor of Applied Mathematics and Mechanics in the Royal College of Science for Ireland. 3 Idrone-terrace, Blackrock, Co. Dublin.
1857. ‡Hennessy, Sir John Pope, K.C.M.G., Governor and Commander-in-Chief of Hong Kong.
1873. *Henrici, Olaus M. F. E., Ph.D., F.R.S., Professor of Applied Mathematics in University College, London. Meldorf Cottage, Greenhill Park, Harlesden, London, N.W.
Henry, Franklin. Portland-street, Manchester.

Year of Election.

Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell, M.P. Stratheden House, Hyde Park, London, W.
1874. ‡Henry, Rev. P. Shuldam, D.D., M.R.I.A. Belfast.
*Henry, William Charles, M.D., F.R.S., F.G.S., F.R.G.S., F.C.S. Haffield, near Ledbury, Herefordshire.
1870. ‡Henty, William. 12 Medina-villas, Brighton.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Baldwyns, Bexley, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
Hepburn, Thomas. Clapham, London, S.W.
1871. ‡*Hepburn, Thomas H. St. Mary Cray, Kent.*
Hepworth, John Mason. Ackworth, Yorkshire.
1856. ‡Hepworth, Rev. Robert. 2 St. James's-square, Cheltenham.
1866. ‡Herrick, Perry. Bean Manor Park, Loughborough.
1871. *Herschel, Professor Alexander S., B.A., F.R.A.S. College of Science, Newcastle-on-Tyne.
1874. §Herschel, Major John, R.E., F.R.S., F.R.A.S. Mussoorie, N. W. P. India. (Care of Messrs. H. Robertson & Co., 5 Crosby-square, London, E.C.)
1865. ‡Heslop, Dr. Birmingham.
1873. ‡*Heugh, John. Gaunt's House, Wimborne, Dorset.*
Hey, The Ven. Archdeacon, M.A., F.C.P.S. Clifton, York.
1881. §Hey, Rev. William Croser, M.A. Clifton, York.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1866. ‡Heymann, L. West Bridgford, Nottinghamshire.
1879. §Heywood, A. Percival. Duffield Bank, Derby.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
*Heywood, James, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S. 26 Kensington Palace-gardens, London, W.
1861. *Heywood, Oliver. Claremont, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.
1875. ‡Hicks, Henry, M.D., F.G.S. Heriot House, Hendon, Middlesex, N.W.
1881. §Hicks, Thomas. 2 George's-terrace, Harrogate.
1877. §Hicks, W. M., M.A. St. John's College, Cambridge.
1864. *Hiern, W. P., M.A. Castle House, Barnstaple.
1854. *Higgin, Edward. Troston Lodge, near Bury St. Edmunds.
1861. *Higgin, James. Lancaster-avenue, Fennel-street, Manchester.
1875. ‡Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.
1871. ‡Higgins, Clement, B.A., F.C.S. 103 Holland-road, Kensington, London, W.
1854. ‡Higgins, Rev. Henry H., M.A. The Asylum, Rainhill, Liverpool.
1861. *Higgins, James. Holmwood, Turvey, near Bedford.
1870. ‡Higginson, Alfred. 135 Tulse Hill, London, S.W.
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
Hill, Arthur. Bruce Castle, Tottenham, Middlesex.
1880. §§Hill, Benjamin. Cwmdwr, near Clydach, Swansea.
1872. §Hill, Charles, F.S.A. Rockhurst, West Hoathley, East Grinstead.
*Hill, Rev. Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1881. §Hill, Rev. Edwin, M.A. St. John's College, Cambridge.
1857. §Hill, John, C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.
1871. ‡Hill, Lawrence. The Knowe, Greenock.
1881. §Hill, Pearson. 50 Belsize Park, London, N.W.

Year of Election.

1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1871. *Hills, Thomas Hyde. 338 Oxford-street, London, W.
1858. ‡Hincks, Rev. Thomas, B.A., F.R.S. Stancliff House, Clevedon, Somerset.
1870. ‡Hinde, G. J., Ph.D., F.G.S. 11 Glebe Villas, Mitcham, Surrey.
*Hindmarsh, Luke. Alnbank House, Alnwick.
1865. ‡Hinds, James, M.D. Queen's College, Birmingham.
1863. ‡Hinds, William, M.D. Parade, Birmingham.
1881. §Hingston, J. T. Clifton, York.
1861. **Hinmers, William. Cleveland House, Birkdale, Southport.*
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1861. *Hirst, T. Archer, Ph.D., F.R.S., F.R.A.S. Royal Naval College, Greenwich, S.E.; and Athenæum Club, Pall Mall, London, S.W.
1870. ‡Hitchman, William, M.D., LL.D., F.L.S. 29 Erskine-street, Liverpool.
*Hoare, Rev. Canon. Godstone Rectory, Redhill.
Hoare, J. Gurney. Hampstead, London, N.W.
1881. §Hobbes, Robert George. The Dockyard, Chatham.
1864. ‡Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Henry William. 24 Cadogan-place, London, S.W.
1879. §Hobkirk, Charles P., F.L.S. Huddersfield.
1879. §Hobson, John. Tapton Elms, Sheffield.
1866. ‡Hockin, Charles, M.D. 8 Avenue-road, St. John's Wood, London, N.W.
1877. ‡Hockin, Edward. Poughill, Stratton, Cornwall.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *Hodgkin, Thomas. Benwell Dene, Newcastle-on-Tyne.
1880. §Hodgkinson, W. R. Eaton, Ph.D. Science Schools, South Kensington Museum, London, S.W.
1873. *Hodgson, George. Thornton-road, Bradford, Yorkshire.
1873. ‡Hodgson, James. Oakfield, Manningham, Bradford, Yorkshire.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. North Dene, Gateshead.
1865. *Hofmann, August Wilhelm, M.D., LL.D., Ph.D., F.R.S., F.C.S. 10 Dorotheen Strasse, Berlin.
1854. *Holcroft, George. Byron's-court, St. Mary's-gate, Manchester.
1873. *Holden, Isaac. Oakworth House, near Keighley, Yorkshire.
1879. ‡Holland, Calvert Bernard. Ashdell, Broomhill, Sheffield.
1878. *Holland, Rev. F. W., M.A. Evesham.
*Holland, Philip H. 3 Heath-rise, Willow-road, Hampstead, London, N.W.
1865. ‡Holliday, William. New-street, Birmingham.
1866. *Holmes, Charles. 59 London-road, Derby.
1873. ‡Holmes, J. R. Southbrook Lodge, Bradford, Yorkshire.
1876. ‡Holms, Colonel William, M.P. 95 Cromwell-road, South Kensington, London, S.W.
1870. ‡Holt, William D. 23 Edge-lane, Liverpool.
1875. *Hood, John. The Elms, Cotham Hill, Bristol.
1847. ‡Hooker, Sir Joseph Dalton, K.C.S.I., K.C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S., F.G.S., F.R.G.S. Royal Gardens, Kew, Surrey.

Year of Election.

1865. *Hooper, John P. Coventry Park, Streatham, London, S.W.
1877. *Hooper, Samuel F., B.A. Tamworth House, Mitcham Common, Surrey.
1856. ‡Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. Stanton, Bebington, Cheshire.
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1870. *Hopkinson, John, M.A., D.Sc., F.R.S. 78 Holland-road, Kensington, London, W.
1871. *Hopkinson, John, F.L.S., F.G.S. 235 Regent-street, London, W.; and Wansford House, Watford.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.
1876. *Horne, Robert R. 150 Hope-street, Glasgow.
1875. *Horniman, F. J. Surrey House, Forest Hill, London, S.E.
1854. ‡Horsfall, Thomas Berry. Bellamour Park, Rugeley.
1856. ‡Horsley, John H. 1 Ormond-terrace, Cheltenham.
1868. ‡Hotson, W. C. Upper King-street, Norwich.
Houghton, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.R.G.S. Travellers' Club, London, S.W.
1858. ‡Hounsfield, James. Hemsworth, Pontefract.
Hovenden, W. F., M.A. Bath.
1879. *Howard, D. South Frith Lodge, Tonbridge.
1863. ‡Howard, Philip Henry. Corby Castle, Carlisle.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1857. ‡Howell, Henry H., F.G.S. Museum of Practical Geology, Jermyn-street, London, S.W.
1868. ‡Howell, Rev. Canon Hinds. Drayton Rectory, near Norwich.
1865. *Howlett, Rev. Frederick, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡Howorth, H. H. Derby House, Eccles, Manchester.
1854. ‡Howson, The Very Rev. J. S., D.D., Dean of Chester. Chester.
1870. ‡Hubback, Joseph. 1 Brunswick-street, Liverpool.
1835. *Hudson, Henry, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
1842. §Hudson, Robert, F.R.S., F.G.S., F.L.S. Clapham Common, London, S.W.
1879. ‡Hudson, Robert S., M.D. Redruth, Cornwall.
1867. ‡Hudson, William H. H., M.A. 19 Bennet's-hill, Doctors' Commons, London, E.C.; and St. John's College, Cambridge.
1858. *Huggins, William, D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. Upper Tulse Hill, Brixton, London, S.W.
1857. ‡Huggon, William. 30 Park-row, Leeds.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1870. *Hughes, Lewis. Fenwick-court, Liverpool.
1876. *Hughes, Rev. Thomas Edward. Wallfield House, Reigate.
1868. §Hughes, T. M'K., M.A., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1863. ‡*Hughes, T. W. 4 Hawthorne-terrace, Newcastle-on-Tyne.*
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
1867. §Hull, Edward, M.A., F.R.S., F.G.S., Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1861. ‡Hume, Rev. Canon Abraham, D.C.L., LL.D., F.S.A. All Souls' Vicarage, Rupert-lane, Liverpool.

Year of Election.

1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880.§§Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *HUMPHRY, GEORGE MURRAY, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Grove Lodge, Cambridge.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1864. ‡Hunt, W. 72 Pulteney-street, Bath.
1875. *Hunt, William. The Woodlands, Tyndall's Park, Clifton, Bristol.
Hunter, Andrew Galloway. Denholm, Hawick, N.B.
1868. ‡Hunter, Christopher. Alliance Insurance Office, North Shields.
1867. ‡Hunter, David. Blackness, Dundee.
1881. §Hunter, F. W. Newbottle, Fence Houses, Durham.
1881. §Hunter, Rev. John. 38 The Mount, York.
1869. *Hunter, Rev. Robert, F.G.S. Rose Villa, Forest-road, Loughton, Essex.
1879. §HUNTINGTON, A. K., F.C.S., Professor of Metallurgy in King's College, London. Abbeville House, Arkwright-road, Hampstead, London, N.W.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1875. ‡Hurnard, James. Lexden, Colchester, Essex.
1869. ‡Hurst, George. Bedford.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
Husband, William Dalla. May Bank, Bournemouth.
1876. ‡Hutchinson, John. 22 Hamilton Park-terrace, Glasgow.
1876. ‡*Hutchison, Peter*. 28 *Berkeley-terrace, Glasgow.*
1868. *Hutchison, Robert, F.R.S.E. 29 Chester-street, Edinburgh.
Hutton, Crompton. Putney Park, Surrey, S.W.
1864. *Hutton, Darnton. (Care of Arthur Lupton, Esq., Headingley, near Leeds.)
1857. ‡Hutton, Henry D. 10 Lower Mountjoy-street, Dublin.
1861. *HUTTON, T. MAXWELL. Summerhill, Dublin.
1852. ‡HUXLEY, THOMAS HENRY, Ph.D., LL.D., F.R.S., F.L.S., F.G.S., Professor of Natural History in the Royal School of Mines. 4 Marlborough-place, London, N.W.
Hyde, Edward. Dukinfield, near Manchester.
1871. *Hyett, Francis A. Painswick House, Stroud, Gloucestershire.

1879. §Ibbotson, H. J. 26 Collegiate-crescent, Sheffield.
Ihne, William, Ph.D. Heidelberg.
1873. §Ikin, J. I. 19 Park-place, Leeds.
1861. ‡Iles, Rev. J. H. Rectory, Wolverhampton.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1881. §Ingham, John. 28 St. Saviourgate, York.
1876. ‡Inglis, Anthony. Broomhill, Partick, Glasgow.
1871. ‡INGLIS, The Right Hon. JOHN, D.C.L., LL.D., Lord Justice General of Scotland. Edinburgh.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Regius Professor of Greek in the University of Dublin. 2 Wellington-road, Dublin.
1870. *Inman, William. Upton Manor, Liverpool.
1857. ‡Irvine, Hans, M.A., M.B. 1 Rutland-square, Dublin.
1862. ‡ISELIN, J. F., M.A., F.G.S. South Kensington Museum, London, S.W.

Year of Election.

1881. §Ishiguro, Isoji. The Japanese Legation, 9 Cavendish-square, London, W.
1863. *Ivory, Thomas. 23 Walker-street, Edinburgh.

1865. ‡Jabet, George. Wellington-road, Handsworth, Birmingham.
1870. ‡Jack, James. 26 Abercromby-square, Liverpool.
1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1876. ‡*Jack, William.* 19 *Lansdowne-road, Notting Hill, London, W.*
1879. §Jackson, Arthur, F.R.C.S. Wilkinson-street, Sheffield.
1874. *Jackson, Frederick Arthur. Cheadle, Cheshire.
1866. ‡Jackson, H. W., F.R.A.S., F.G.S. 15 The Terrace, High-road, Lewisham, S.E.
1869. §Jackson, Moses. The Vale, Ramsgate.
1863. *Jackson-Gwilt, Mrs. H. Moonbeam Villa, The Grove, New Wimbledon, London, S.W.
1874. *Jaffe, John. Cambridge Villa, Strandtown, near Belfast.
1865. *Jaffray, John. Park-grove, Edgbaston, Birmingham.
1872. ‡James, Christopher. 8 Laurence Pountney Hill, London, E.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1863. *James, Sir Walter, Bart., F.G.S. 6 Whitehall-gardens, London, S.W.
1858. ‡James, William C. Woodside, Plymouth.
1881. §Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1876. ‡Jamieson, J. L. K. The Mansion House, Govan, Glasgow.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. ‡Jardine, Alexander. Jardine Hall, Lockerby, Dumfriesshire.
1870. ‡Jardine, Edward. Beach Lawn, Waterloo, Liverpool.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
Jarrett, Rev. Thomas, M.A., Professor of Arabic in the University of Cambridge. Trunch, Norfolk.
1870. §§Jarrold, John James. London-street, Norwich.
1862. ‡Jeakes, Rev. James, M.A. 54 Argyll-road, Kensington, London, W.
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1856. ‡Jeffery, Henry M., M.A., F.R.S. 438 High-street, Cheltenham.
1855. *Jeffray, John. Cardowan House, Millerston, Glasgow.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. 5 Brick-court, Temple, London, E.C.
1861. *Jeffreys, J. Gwyn, LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S. Athenæum Club, Pall Mall, London, S.W.
1852. ‡Jellett, Rev. John H., B.D., M.R.I.A., Provost of Trinity College, Dublin.
1881. §Jellicoe, C. W. A. Southampton.
1862. §Jenkin, H. C. Fleeming, F.R.S., M.I.C.E., Professor of Civil Engineering in the University of Edinburgh. 3 Great Stuart-street, Edinburgh.
1873. §Jenkins, Major-General J. J. 14 St. James's-square, London, S.W.
1880. *Jenkins, John Jones, M.P. The Grange, Swansea.
Jennette, Matthew. 106 Conway-street, Birkenhead.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1872. ‡Jennings, W. Grand Hotel, Brighton.
1878. ‡Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.
*Jerram, Rev. S. John, M.A. Chobham Vicarage, Woking Station, Surrey.

Year of Election.

1872. ‡Jesson, Thomas. 7 Upper Wimpole-street, Cavendish-square, London, W.

Jessop, William, jun. Butterley Hall, Derbyshire.

1870. *Jevons, W. Stanley, M.A., LL.D., F.R.S. 2 The Chestnuts, West Heath, Hampstead, London, N.W.

1872. *Joad, George C. Oakfield, Wimbledon Park, Surrey, S.W.

1871. *Johnson, David, F.C.S., F.G.S. Barrelwell House, Chester.

1881. §Johnson, Captain Edmond Cecil. 12 Cadogan-place, London, S.W.

1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.

1875. §Johnson, James Henry, F.G.S., F.S.A. 73 Albert-road, Southport.

1866. ‡Johnson, John G. 18A Basinghall-street, London, E.C.

1872. ‡Johnson, J. T. 27 Dale-street, Manchester.

1861. ‡Johnson, Richard. 27 Dale-street, Manchester.

1870. §§Johnson, Richard C., F.R.A.S. Higher Bebington Hall, Birkenhead.

1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.

1881. §Johnson, Samuel George. Municipal Offices, Nottingham.

*Johnson, Thomas. Bache Hurst, Liverpool-road, Chester.

1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham.

1864. ‡Johnston, David. 13 Marlborough-buildings, Bath.

1859. ‡Johnston, James. Newmill, Elgin, N.B.

1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.W.

*Johnstone, James. Alva House, Alva, by Stirling, N.B.

1864. ‡Johnstone, John. 1 Barnard-villas, Bath.

1876. ‡Johnstone, William. 5 Woodside-terrace, Glasgow.

1864. ‡Jolly, Thomas. Park View-villas, Bath.

1871. §Jolly, William, F.R.S.E., F.G.S., H.M. Inspector of Schools. Inverness, N.B.

1881. §Jones, Alfred Orlando, M.D. Belton House, Harrogate.

1849. ‡Jones, Baynham. Selkirk Villa, Cheltenham.

1856. ‡Jones, C. W. 7 Grosvenor-place, Cheltenham.

1877. ‡Jones, Henry C., F.C.S. 166 Blackstock-road, London, N.

1881. §Jones, J. Vivian. Firth College, Sheffield.

*Jones, Robert. 2 Castle-street, Liverpool.

1873. ‡Jones, Theodore B. 1 Finsbury-circus, London, E.C.

1880. §Jones, Thomas. 15 Gower-street, Swansea.

1860. ‡Jones, Thomas Rupert, F.R.S., F.G.S., Professor of Geology at the Staff College, Sandhurst. Powis Villa, Camberley, Surrey.

1864. §Jones, Sir Willoughby, Bart., F.R.G.S. Cranmer Hall, Fakenham, Norfolk.

1875. *Jose, J. E. 3 Queen-square, Bristol.

*Joule, Benjamin St. John B., J.P. 28 Leicester-street, Southport, Lancashire.

1842. *Joule, James Prescott, LL.D., F.R.S., F.C.S. 12 Wardle-road, Sale, near Manchester.

1847. ‡Jowett, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.

1858. ‡Jowett, John. Leeds.

1879. ‡Jowitt, A. Hawthorn Lodge, Clarkehouse-road, Sheffield.

1872. ‡Joy, Algernon. Junior United Service Club, St. James's, London, S.W.

1848. *Joy, Rev. Charles Ashfield. Grove Parsonage, Wantage, Berkshire.

Joy, Rev. John Holmes, M.A. 3 Coloney-terrace, Tunbridge Wells.

*Jubb, Abraham. Halifax.

1870. ‡Judd, John Wesley, F.R.S., F.G.S. 4 Auriol-road, West Kensington, London, W.

Year of
Election.
1868. *Kaines, Joseph, M.A., D.Sc. 401 Finsbury-pavement, London, E.C.
Kane, Sir Robert, M.D., LL.D., F.R.S., M.R.I.A., F.C.S., Principal of the Royal College of Cork. Fortland, Killiney, Co. Dublin.
1857. ‡Kavanagh, James W. Grenville, Rathgar, Ireland.
1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, London, W.
Kay, John Cunliff. Fairfield Hall, near Skipton.
Kay, Robert. Haugh Bank, Bolton-le-Moors.
1847. *Kay, Rev. William, D.D. Great Leghs Rectory, Chelmsford.
1872. ‡Keames, William M. 5 Lower Rock-gardens, Brighton.
1875. ‡Keeling, George William. Tuthill, Lydney.
1881. §Keeping, Walter, M.A., F.G.S. The Museum, York.
1878. *Kelland, William Henry. 110 Jermyn-street, London, S.W.; and Grettans, Bow, North Devon.
1876. ‡Kelly, Andrew G. The Manse, Alloa, N.B.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1853. ‡Kemp, Rev. Henry William, B.A. The Charter House, Hull.
1875. ‡Kennedy, Alexander B. W., C.E., Professor of Engineering in University College, London. 9 Bartholomew-road, London, N.W.
1876. ‡Kennedy, Hugh. Redclyffe, Partickhill, Glasgow.
1865. ‡*Kenrick, William. Norfolk-road, Edgbaston, Birmingham.*
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1857. ‡Kent, William T., M.R.D.S. 51 Rutland-square, Dublin.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1855. *Ker, Robert. Dougalston, Milngavie, N.B.
1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.
1881. §Kermode, Philip. Ramsay, Isle of Man.
1868. ‡Kerrison, Roger. Crown Bank, Norwich.
1869. *Kesselmeyer, Charles A. 1 Peter-street, Manchester.
1869. *Kesselmeyer, William Johannes. 1 Peter-street, Manchester.
1861. *Keymer, John. Parker-street, Manchester.
1876. ‡Kidston, J. B. West Regent-street, Glasgow.
1876. ‡Kidston, William. Ferniegair, Helensburgh, N.B.
1865. *Kinahan, Edward Hudson, M.R.I.A. 11 Merrion-square North, Dublin.
1878. ‡Kinahan, Edward Hudson, jun. 11 Merrion-square North, Dublin.
1860. ‡Kinahan, G. Henry, M.R.I.A., Geological Survey of Ireland. 14 Hume-street, Dublin.
1875. *Kinch, Edward, F.C.S. Agricultural College, Cirencester.
1872. *King, Mrs. E. M. 34 Cornwall-road, Westbourne Park, London, W.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Herbert Poole. Theological College, Salisbury.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1870. §King, John Thomson, C.E. 4 Clayton-square, Liverpool.
King, Joseph. Welford House, Greenhill, Hampstead, London, N.W.
1864. §King, Kelburne, M.D. 27 George-street, and Royal Institution, Hull.
1860. *King, Mervyn Kersteman. 1 Vittoria-square, Clifton, Bristol.
1875. *King, Percy L. Avonside, Clifton, Bristol.
1870. ‡King, William. 13 Adelaide-terrace, Waterloo, Liverpool.
King, William Poole, F.G.S. Avonside, Clifton, Bristol.
1869. ‡Kingdon, K. Taddiford, Exeter.
1861. ‡Kingsley, John. Ashfield, Victoria Park, Manchester.
1876. §Kingston, Thomas. Strawberry House, Chiswick, Middlesex.

Year of Election.

1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1875. §KINGZETT, CHARLES T., F.C.S. 17 Lansdowne-road, Tottenham, Middlesex.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1867. *KINNAIRD, The Right Hon. Lord. 2 Pall Mall East, London, S.W.; and Rossie Priory, Inchture, Perthshire.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1863. ‡*Kirkaldy, David. 28 Bartholomew-road North, London, N.W.*
1860. ‡KIRKMAN, Rev. THOMAS P., M.A., F.R.S. Croft Rectory, near Warrington.
Kirkpatrick, Rev. W. B., D.D. 48 North Great George-street, Dublin.
1876. *Kirkwood, Anderson, LL.D., F.R.S.E. 12 Windsor-terrace West, Hillhead, Glasgow.
1875. ‡Kirsop, John. 6 Queen's-crescent, Glasgow.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1881. §Kitching, Langley. 50 Caledonian-road, Leeds.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1870. ‡Kneeshaw, Henry. 2 Gambier-terrace, Liverpool.
1836. Knipe, J. A. Botcherby, Carlisle.
1872. *Knott, George, LL.B., F.R.A.S. Knowles Lodge, Cuckfield, Hayward's Heath, Sussex.
1873. *Knowles, George. Moorhead, Shipley, Yorkshire.
1872. ‡Knowles, James. The Hollies, Clapham Common, S.W.
1842. *Knowles, John. The Lawn, Rugby.*
1870. ‡Knowles, Rev. J. L. 103 Earl's Court-road, Kensington, London, W.
1874. ‡Knowles, William James. Cullybackey, Belfast, Ireland.
1876. ‡Knox, David N., M.A., M.B. 8 Belgrave-terrace, Hillhead, Glasgow.
*Knox, George James. 2 Coleshill-street, Eaton-square, London, S.W.
1835. *Knox, Thomas Perry. Union Club, Trafalgar-square, London, W.C.*
1875. *Knubley, Rev. E. P. Staveley Rectory, Leeds.
1881. §Kurobe, Hiroo. Legation of Japan, 9 Cavendish-square, London, W.
1870. ‡Kynaston, Josiah W., F.C.S. St. Helen's, Lancashire.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.

1858. §Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1859. §Ladd, William, F.R.A.S. 11 & 13 Beak-street, Regent-street, London, W.
1870. ‡Laird, H. H. Birkenhead.
1870. §Laird, John, jun. Grosvenor-road, Claughton, Birkenhead.
1880. *Lake, Samuel. Milford Docks, Milford Haven.
1877. §Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. 2 Longford-terrace, Monkstown, Co. Dublin.
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 8 The Circus, Greenwich, London, S.E.
1859. ‡Lang, Rev. John Marshall, D.D. Barony, Glasgow.
1864. ‡Lang, Robert. Langford Lodge, College-road, Clifton, Bristol.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
*Langton, William. Docklands, Ingatestone, Essex.
1865. ‡LANKESTER, E. RAY, M.A., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London. Exeter College, Oxford; and 11 Wellington Mansions, North Bank, London, N.W.

Year of
Election.

1880. *Lansdell, Rev. Henry. Eyre Cottage, Blackheath, London, S.E.
Lanyon, Sir Charles. The Abbey, White Abbey, Belfast.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1881. §Larmor, Joseph, M.A., Professor of Natural Philosophy in Queen's College, Galway.
1861. *Latham, Arthur G. Lower King-street, Manchester.
1870. *Latham, Baldwin, C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1870. ‡Laughton, John Knox, M.A., F.R.A.S., F.R.G.S. Royal Naval College, Greenwich, S.E.
1870. *Law, Channell. Sydney Villa, 36 Outram-road, Addiscombe, Croydon.
1878. ‡Law, Henry, C.E. 5 Queen Anne's-gate, London, S.W.
1857. ‡Law, Hugh, Q.C. 9 Fitzwilliam-square, Dublin.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
Lawley, The Hon. Francis Charles. Escrick Park, near York.
Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1881. §Lawrence, Rev. F., B.A. St. Mary's Rectory, Castlegate, York.
1875. ‡Lawson, George, Ph.D., LL.D., Professor of Chemistry and Botany. Halifax, Nova Scotia.
1857. ‡Lawson, The Right Hon. James A., LL.D., M.R.I.A. 27 Fitzwilliam-street, Dublin.
1868. *Lawson, M. Alexander, M.A., F.L.S., Professor of Botany in the University of Oxford. Botanic Gardens, Oxford.
1863. ‡*Lawton, Benjamin C. Neville Chambers, 44 Westgate-street, Newcastle-upon-Tyne.*
1853. ‡Lawton, William. 5 Victoria-terrace, Derringham, Hull.
1865. ‡Lea, Henry. 35 Paradise-street, Birmingham.
1857. ‡Leach, Colonel R. E. Mountjoy, Phœnix Park, Dublin.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. Old Change, London, E.C.; and Painshill, Cobham.
1847. *Leatham, Edward Aldam, M.P. Whitley Hall, Huddersfield; and 46 Eaton-square, London, S.W.
1844. *Leather, John Towlerton, F.S.A. Leventhorpe Hall, near Leeds.
1858. ‡*Leather, John W. Newton-green, Leeds.*
1863. ‡Leavers, J. W. The Park, Nottingham.
1872. ‡Lebour, G. A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne. Weedpark House, Dipton, Lintz Green, Co. Durham.
1858. *Le Cappelain, John. Wood-lane, Highgate, London, N.
1861. ‡Lee, Henry. Irwell House, Lower Broughton, Manchester.
1853. *Lee, John Edward, F.G.S., F.S.A. Villa Syracusa, Torquay.
1859. ‡*Lees, William. Link Vale Lodge, Viewforth, Edinburgh.*
*Leese, Joseph. Glenfield, Altrincham, Manchester.
1881. §Le Feuvre, J. E. Southampton.
1872. ‡Lefevre, G. Shaw, M.P., F.R.G.S. 18 Bryanston-square, London, W.
*Lefroy, Lieut.-General Sir John Henry, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S. Tasmania.
*Legh, Lieut.-Colonel George Cornwall. High Legh Hall, Cheshire.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1868. ‡Leicester, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1856. ‡Leigh, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.

Year of Election.

1870. ‡Leighton, Andrew. 35 High-park-street, Liverpool.
1880. §Leighton, William Henry, F.G.S. 2 Merton-place, Chiswick, S.W.
1867. §Leishman, James. Gateacre Hall, Liverpool.
1870. ‡Leister, G. F. Gresbourn House, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1863. *LENDY, Major AUGUSTE FREDERIC, F.L.S., F.G.S. Sunbury House, Sunbury, Middlesex.
1867. ‡Leng, John. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1861. ‡Lennox, A. C. W. 7 Beaufort-gardens, Brompton, London, S.W.
Lentaigne, Sir John, C.B., M.D. Tallaght House, Co. Dublin; and 1 Great Denmark-street, Dublin.
Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1871. §LEONARD, HUGH, F.G.S., M.R.I.A., F.R.G.S.I. St. David's, Malahide-road, Co. Dublin.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1861. ‡Leppoc, Henry Julius. Kersal Crag, near Manchester.
1872. ‡Lermit, Rev. Dr. School House, Dedham.
1871. ‡Leslie, Alexander, C.E. 72 George-street, Edinburgh.
1856. ‡Leslie, Colonel J. Forbes. Rothienorman, Aberdeenshire.
1852. ‡LESLIE, T. E. CLIFFE, LL.B., Professor of Jurisprudence and Political Economy in Queen's College, Belfast.
1880. §LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1866. §LEVI, Dr. LEONE, F.S.A., F.S.S., F.R.G.S., Professor of Commercial Law in King's College, London. 5 Crown Office-row, Temple, London, E.C.
1879. ‡Lewin, Lieut.-Colonel. Tanhurst, Dorking.
1870. ‡LEWIS, ALFRED LIONEL. 35 Colebrooke-row, Islington, London, N.
1853. ‡Liddell, George William Moore. Sutton House, near Hull.
1860. ‡LIDDELL, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1862. ‡LILFORD, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*LIMERICK, The Right Rev. CHARLES GRAVES, D.D., F.R.S., M.R.I.A., Lord Bishop of. The Palace, Henry-street, Limerick.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1881. §Lindley, William, C.E., F.G.S. 10 Kidbrooke-terrace, Blackheath, London, S.E.
*Lindsay, Charles. Ridge Park, Lanark, N.B.
1870. ‡*Lindsay, Thomas, F.C.S.* 288 *Renfrew-street, Glasgow.*
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
Lingwood, Robert M., M.A., F.L.S., F.G.S. 1 Derby-villas, Cheltenham.
1876. §Linn, James. Geological Survey Office, India-buildings, Edinburgh.
1870. §Lister, Thomas. Victoria-crescent, Barnsley, Yorkshire.
1876. ‡Little, Thomas Evelyn. 42 Brunswick-street, Dublin.
Littledale, Harold. Liscard Hall, Cheshire.
1861. *LIVEING, G. D., M.A., F.R.S., F.C.S., Professor of Chemistry in the University of Cambridge. Cambridge.
1876. *Liversidge, Archibald, F.C.S., F.G.S., F.R.G.S., Professor of Geology and Mineralogy in the University of Sydney, N.S.W. (Care of Messrs. Trübner & Co., Ludgate Hill, London, E.C.)
1864. §§Livesay, J. G. Cromarty House, Ventnor, Isle of Wight.
1880. §§Llewelyn, John T. D. Penllegare, Swansea.
Lloyd, Rev. A. R. Hengold, near Oswestry.
Lloyd, Rev. C., M.A. Whittington, Oswestry.

Year of Election.

1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B. Edgbaston-grove, Birmingham.
*Lloyd, George, M.D., F.G.S. Acock's-green, near Birmingham.
1865. ‡Lloyd, John. Queen's College, Birmingham.
Lloyd, Rev. Rees Lewis. Belper, Derbyshire.
1877. *Lloyd, Sampson Samuel. Moor Hall, Sutton Coldfield.
1865. *Lloyd, Wilson, F.R.G.S. Myrod House, Wednesbury.
1854. *Lobley, James Logan, F.G.S., F.R.G.S. 59 Clarendon-road, Kensington Park, London, W.; and New Athenæum Club, S.W.
1853. *Locke, John. 133 Leinster-road, Dublin.
1867. *Locke, John. 83 Addison-road, Kensington, London, W.
1863. ‡Lockyer, J. Norman, F.R.S., F.R.A.S. 16 Penywern-road, South Kensington, London, S.W.
1875. *Lodge, Oliver J., D.Sc. 26 Waverley-road, Sefton Park, Liverpool.
1868. ‡Login, Thomas, C.E., F.R.S.E. India.
1862. ‡Long, Andrew, M.A. King's College, Cambridge.
1876. ‡Long, H. A. Charlotte-street, Glasgow.
1872. ‡Long, Jeremiah. 50 Marine Parade, Brighton.
1871. *Long, John Jex. 727 Duke-street, Glasgow.
1851. ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1866. §Longdon, Frederick. Osmaston-road, Derby.
Longfield, The Right Hon. Mountifort, LL.D., M.R.I.A., Regius Professor of Feudal and English Law in the University of Dublin. 47 Fitzwilliam-square, Dublin.
1859. ‡Longmuir, Rev. John, M.A., LL.D. 14 Silver-street, Aberdeen.
1875. *Longstaff, George Blundell, M.A., M.B., F.C.S. Southfield Grange, Wandsworth, S.W.
1871. §Longstaff, George Dixon, M.D., F.C.S. Southfields, Wandsworth, S.W.; and 9 Upper Thames-street, London, E.C.
1872. *Longstaff, Lieut.-Colonel Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, S.W.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, S.W.
1861. *Lord, Edward. Adamroyd, Todmorden.
1863. ‡Losh, W. S. Wreay Syke, Carlisle.
1876. *Love, James, F.R.A.S. 12 Regent's Park-terrace, Strathbungo, Glasgow.
1875. *Lovett, W. J. 96 Lionel-street, Birmingham.
1867. *Low, James F. Monifieth, by Dundee.
1863. *Lowe, Lieut.-Colonel Arthur S. H., F.R.A.S. 76 Lancaster-gate, London, W.
1861. *Lowe, Edward Joseph, F.R.S., F.R.A.S., F.L.S., F.G.S., F.M.S. Shirenewton, near Chepstow.
1870. ‡Lowe, G. C. 67 Cecil-street, Greenheys, Manchester.
1868. ‡Lowe, John, M.D. King's Lynn.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1881. §Lubbock, Arthur Rolfe. High Elms, Hayes, Kent.
1853. *Lubbock, Sir John, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. (President.) High Elms, Hayes, Kent.
1881. §Lubbock, John B. High Elms, Hayes, Kent.
1870. §Lubbock, Montague, M.D. 19 Grosvenor-street, London, W.
1878. ‡Lucas, Joseph. Tooting Graveney, London, S.W.
1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
1875. §Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1881. §Luden, C. M. 4 Bootham-terrace, York.
1867. *Luis, John Henry. Cidhmore, Dundee.

Year of Election.

1873. ‡Lumley, J. Hope Villa, Thornbury, near Bradford, Yorkshire.
1866. *Lund, Charles. 48 Market-street, Bradford, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. Teviot Bank, Newport Road, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1858. *Lupton, Arthur. Headingley, near Leeds.
1864. *Lupton, Darnton. The Harehills, near Leeds.
1874. *Lupton, Sydney, M.A. Harrow.
1864. *Lutley, John. Brockhampton Park, Worcester.
1871. ‡*Lyell, Leonard. 42 Regent's Park-road, London, N.W.*
1874. ‡Lynam, James, C.E. Ballinasloe, Ireland.
1857. ‡Lyons, Robert D., M.B., M.R.I.A. 8 Merrion-square West, Dublin.
1878. ‡Lyte, Cecil Maxwell. Cotford, Oakhill-road, Putney, S.W.
1862. *Lyte, F. Maxwell, F.C.S. Cotford, Oakhill-road, Putney, S.W.

1852. ‡McAdam, Robert. 18 College-square East, Belfast.
1854. *Macadam, Stevenson, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1876. *Macadam, William Ivison. Surgeons' Hall, Edinburgh.
1868. ‡Macalister, Alexander, M.D., F.R.S., Professor of Zoology in the University of Dublin. 13 Adelaide-road, Dublin.
1878. §MacAlister, Donald, B.A., B.Sc. St. Bartholomew's Hospital, London, E.C.
1879. §MacAndrew, James J. Lukesland, Ivybridge, South Devon.
1866. *M'Arthur, A., M.P. Raleigh Hall, Brixton Rise, London, S.W.
1838. Macaulay, Henry. 14 Clifton Bank, Rotherham, Yorkshire.
1840. Macaulay, James, A.M., M.D. 25 Carlton-road, Maida Vale, London, N.W.
1871. ‡*M'Bain, James, M.D., R.N. Logie Villa, York-road, Trinity, Edinburgh.*
*MacBrayne, Robert. Messrs. Black and Wingate, 5 Exchange-square, Glasgow.
1866. ‡M'Callan, Rev. J. F., M.A. Basford, near Nottingham.
1863. ‡M'Calmont, Robert. Gatton Park, Reigate.
1855. ‡M'Cann, Rev. James, D.D., F.G.S. 8 Oak Villas, Lower Norwood, Surrey, S.E.
1876. *M'Clelland, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1840. M'Clelland, James, F.S.S. 32 Pembridge-square, London, W.
1868. ‡M'Clintock, Rear-Admiral Sir Francis L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. *M'Clure, J. H. The Wilderness, Richmond, Surrey.
1874. ‡M'Clure, Sir Thomas, Bart. Belmont, Belfast.
1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.
1859. *M'Connell, David C., F.G.S. Care of Mr. H. K. Lewis, 136 Gower-street, London, W.C.
1858. ‡M'Connell, J. E. Woodlands, Great Missenden.
1876. ‡M'Culloch, Richard. 109 Douglas-street, Blythswood-square, Glasgow.
1871. ‡M'Donald, William. Yokohama, Japan. (Care of R. K. Knevitt, Esq., Sun-court, Cornhill, E.C.)
1878. ‡McDonnell, Alexander. St. John's, Island Bridge, Dublin.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1878. ‡McDonnell, James. 32 Upper Fitzwilliam-street, Dublin.
1878. ‡McDonnell, Robert, M.D., F.R.S., M.R.I.A. 14 Lower Pembroke-street, Dublin.

Year of Election.

*M'Ewan, John. 3 Douglas-terrace, Stirling, N.B.
1881. §Macfarlane, A., D.Sc., F.R.S.E. The University, Edinburgh.
1871. ‡M'Farlane, Donald. The College Laboratory, Glasgow.
1855. *Macfarlane, Walter. 22 Park-circus, Glasgow.
1879. §Macfarlane, Walter, jun. 22 Park-circus, Glasgow.
1854. *Macfie, Robert Andrew. Dreghorn, Colinton, Edinburgh.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1855. ‡MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
1872. ‡M'George, Mungo. Nithsdale, Laurie Park, Sydenham, S.E.
1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.
1855. ‡*MacGregor, James Watt. 2 Laurence-place, Partick, Glasgow.*
1876. ‡M'Grigor, Alexander B., LL.D. 19 Woodside-terrace, Glasgow.
1859. ‡M'Hardy, David. 54 Netherkinkgate, Aberdeen.
1874. ‡MacIlwaine, Rev. Canon, D.D., M.R.I.A. Ulsterville, Belfast.
1859. ‡Macintosh, John. Middlefield House, Woodside, Aberdeen.
1867. *M'Intosh, W. C., M.D., F R.S. L. & E., F.L.S. Murthly, Perthshire.
1854. *MacIver, Charles. 8 Abercromby-square, Liverpool.
1871. ‡Mackay, Rev. A., LL.D., F.R.G.S. 2 Hatton-place, Grange, Edinburgh.
1873. ‡McKendrick, John G., M.D., F.R.S.E., Professor of the Institutes of Medicine in the University of Glasgow, and Fullerian Professor of Physiology in the Royal Institution, London.
1880. *Mackenzie, Colin. Junior Athenæum Club, Piccadilly, London, W.
1865. ‡Mackeson, Henry B., F.G.S. Hythe, Kent.
1872. *Mackey, J. A. 24 Buckingham-place, Brighton.
1867.§§*Mackie, Samuel Joseph, C.E., F.G.S. 22 Eldon-road, Kensington, London, W.*
*Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.
1865. ‡Mackintosh, Daniel, F.G.S. Whitford-road, Tranmere, Birkenhead.
1850. ‡*Macknight, Alexander. 12 London-street, Edinburgh.*
1867. ‡Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *McLachlan, Robert, F.R.S., F.L.S. 39 Limes-grove, Lewisham, S.E.
1873. ‡McLandsborough, John, C.E., F.R.A.S., F.G.S. South Park Villa, Harrogate, Yorkshire.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1864. ‡MacLaren, Duncan. Newington House, Edinburgh.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1876. ‡*M'Lean, Charles. 6 Claremont-terrace, Glasgow.*
1876. ‡*M'Lean, Mrs. Charles. 6 Claremont-terrace, Glasgow.*
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Campden Hill-road, London, W.
1868. §M'Leod, Herbert, F.R.S., F.C.S. Indian Civil Engineering College, Cooper's Hill, Egham.
1875. ‡Macliver, D. 1 Broad-street, Bristol.
1875. ‡Macliver, P. S. 1 Broad-street, Bristol.
1861. *Maclure, John William, F.R.G.S., F.S.S. Whalley Range, Manchester.
1878. *M'Master, George, M.A., J.P. Donnybrook, Ireland.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey, S.W.
1874. ‡MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1871. ‡M'Nab, William Ramsay, M.D., Professor of Botany in the Royal College of Science, Dublin. 4 Vernon-parade, Clontarf, Dublin.
1870. ‡Macnaught, John, M.D. 74 Huskisson-street, Liverpool.
1867. §M'Neill, John. Balhousie House, Perth.

Year of Election.

MacNeill, The Right Hon. Sir John, G.C.B., F.R.S.E., F.R.G.S. Granton House, Edinburgh.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1852. *Macrory, Adam John. Duncairn, Belfast.
*Macrory, Edmund, M.A. 2 Ilchester-gardens, Prince's-square, London, W.
1876. *Mactear, James. 16 Burnbank-gardens, Glasgow.
1855. ‡Macvicar, Rev. John Gibson, D.D., LL.D. Moffat, N.B.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Philip. 48 Gloucester-place, Portman-square, London, W.
1879. ‡Mahomed, F. A. 13 St. Thomas-street, London, S.E.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1869. ‡Main, Robert. Admiralty, Whitehall, London, S.W.
1866. ‡Major, Richard Henry, F.S.A., Sec. R.G.S. British Museum, London, W.C.
*Malahide, The Right Hon. Lord Talbot de, M.A., D.C.L., F.R.S., F.G.S., F.S.A., M.R.I.A. Malahide Castle, Co. Dublin.
*Malcolm, Frederick. Morden College, Blackheath, London, S.E.
1881. §Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1863. ‡Maling, C. T. Lovaine-crescent, Newcastle-on-Tyne.
1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, U.S.
1846. ‡Manby, Charles, F.R.S., F.G.S. 60 Westbourne-terrace, Hyde Park, London, W.
1870. ‡Manifold, W. H. 45 Rodney-street, Liverpool.
1866. §Mann, Robert James, M.D., F.R.A.S. 5 Kingsdown-villas, Wandsworth Common, S.W.
Manning, His Eminence Cardinal. Archbishop's House, Westminster, S.W.
1866. ‡Manning, John. Waverley-street, Nottingham.
1878. §Manning, Robert. 4 Upper Ely-place, Dublin.
1864. ‡Mansel, J. C. Long Thorns, Blandford.
1870. ‡Marcoartu, Senor Don Arturo de. Madrid.
1864. ‡Markham, Clements R., C.B., F.R.S., F.L.S., Sec.R.G.S., F.S.A. 21 Eccleston-square, Pimlico, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
*Marling, Samuel S. Stanley Park, Stroud, Gloucestershire.
1881. *Marr, John Edward, B.A., F.G.S. St. John's College, Cambridge.
1871. ‡Marreco, A. Friere-. College of Physical Science, Newcastle-on-Tyne.
1857. ‡Marriott, William, F.C.S. Grafton-street, Huddersfield.
1842. Marsden, Richard. Norfolk-street, Manchester.
1870. ‡Marsh, John. Rann Lea, Rainhill, Liverpool.
1865. ‡Marsh, J. F. Hardwick House, Chepstow.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1881. §Marshall, D. H. Greenhill Cottage, Rothesay.
1881. §Marshall, John. Church Institute, Leeds.
1876. ‡Marshall, Peter. 6 Parkgrove-terrace, Glasgow.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
1849. *Marshall, William P. 14 Augustus-road, Birmingham.
1865. §Marten, Edward Bindon. Pedmore, near Stourbridge.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1878. ‡Martin, H. Newell. Christ's College, Cambridge.
1871. ‡Martin, Rev. Hugh, M.A. Greenhill Cottage, Lasswade, by Edinburgh.

Year of
Election.

1836. Martin, Studley. 177 Bedford-street South, Liverpool.
*Martindale, Nicholas. Queen's Park, Chester.
*Martineau, Rev. James, LL.D., D.D. 35 Gordon-square, London, W.C.
1865. ‡Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1875. ‡Martyn, Samuel, M.D. 8 Buckingham-villas, Clifton, Bristol.
1878. ‡Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-street Within, London, E.C.
1847. ‡MASKELYNE, NEVIL STORY, M.P., M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. 39 Cornwall-gardens, London, W.
1861. *Mason, Hugh. Groby Hall, Ashton-under-Lyne.
1879. ‡Mason, James, M.D. Montgomery House, Sheffield.
1868. ‡Mason, James Wood, F.G.S. The Indian Museum, Calcutta. (Care of Messrs. Henry S. King & Co., 65 Cornhill, London, E.C.)
1876. §Mason, Robert. 6 Albion-crescent, Dowanhill, Glasgow.
1876. ‡Mason, Stephen. 9 Rosslyn-terrace, Hillhead, Glasgow.
Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
1870. ‡*Massy, Frederick.* 50 *Grove-street, Liverpool.*
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 60 Harborne-road, Birmingham.
1881. §Mathwin, Henry, B.A. Bickerton House, Southport.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1860. ‡Matthews, Rev. Richard Brown. Shalford Vicarage, near Guildford.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall Hall, Broseley, Shropshire.
1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.
1864. *Maxwell, Francis. Balgrove, North Berwick.
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1868. ‡Mayall, J. E., F.C.S. Stork's Nest, Lancing, Sussex.
1835. Mayne, Edward Ellis. Rocklands, Stillorgan, Ireland.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1863. ‡Mease, George D. Bylton Villa, South Shields.
1881. §Meek, Sir James. Middlethorpe, York.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. H.M. Dockyard, Chatham.
1881. *Meldola, Raphael, F.R.A.S., F.C.S., F.I.C. 21 John-street, Bedford-row, London, W.C.
1867. ‡MELDRUM, CHARLES, M.A., F.R.S., F.R.A.S. Port Louis, Mauritius.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. St. Thomas's Rectory, Brampton, Chesterfield.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1881. §Melrose, James. Clifton, York.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1877. *Menabrea, General Count. 35 Queen's-gate, London, S.W.
1862. ‡MENNELL, HENRY J. St. Dunstan's-buildings, Great Tower-street, London, E.C.

Year of
Election.

1879. §Merivale, John Herman, Professor of Mining in the College of Science, Newcastle-on-Tyne.
1879.§§Merivale, Walter. Engineers' Office, North-Eastern Railway, Newcastle-on-Tyne.
1868. §MERRIFIELD, CHARLES W., F.R.S. 20 Girdler's-road, Brook Green, London, W.
1877. ‡Merrifield, John, Ph.D., F.R.A.S. Gascoigne-place, Plymouth.
1880. §Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1871. ‡*Merson, John. Northumberland County Asylum, Morpeth.*
1872. *Messent, John. 429 Strand, London, W.C.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. ‡MIALL, LOUIS C., F.G.S., Professor of Biology in Yorkshire College, Leeds.
1881. §Mickle, Mrs. H. B. 12 Gillygate, York.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of. Middlesbrough.
1881. §Middleton, A. Morton. Castle Eden, Co. Durham.
1876. *Middleton, Robert T., M.P. 197 West George-street, Glasgow.
1866. ‡Midgley, John. Colne, Lancashire.
1867. ‡Midgley, Robert. Colne, Lancashire.
1881. §MILES, MORRIS. Barron Villa, Hill, Southampton.
1859. ‡Millar, John, J.P. Lisburn, Ireland.
1863. ‡Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road, London, E.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1876. ‡Millar, William. Highfield House, Dennistoun, Glasgow.
1876. ‡Millar, W. J. 145 Hill-street, Garnethill, Glasgow.
1876. ‡Miller, Daniel. 258 St. George's-road, Glasgow.
1875. ‡Miller, George. Brentry, near Bristol.
1861. *Miller, Robert. Poise House, Bosden, near Stockport.
1876. *Miller, Robert. 1 Lily Bank-terrace, Hillhead, Glasgow.
1876. ‡Miller, Thomas Paterson. Morriston House, Cambuslang, N.B.
1868. *Milligan, Joseph, F.L.S., F.G.S., F.R.A.S., F.R.G.S. 6 Craven-street, Strand, London, W.C.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in Anderson's College, Glasgow. 60 John-street, Glasgow.
*Mills, John Robert. 11 Bootham, York.
1880.§§Mills, Mansfieldt H. Tapton-grove, Chesterfield.
Milne, Admiral Sir Alexander, Bart., G.C.B., F.R.S.E. 13 New-street, Spring-gardens, London, S.W.
1867. *MILNE-HOME, DAVID, M.A., F.R.S.E., F.G.S. 10 York-place, Edinburgh.
1864. *MILTON, The Right Hon. Lord, F.R.G.S. 17 Grosvenor-street, London, W.; and Wentworth, Yorkshire.
1880. §Minchin, G. M., M.A. Royal Indian Engineering College, Cooper's Hill, Surrey.
1865. ‡Minton, Samuel, F.G.S. Oakham House, near Dudley.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1876. ‡Mitchell, Andrew. 20 Woodside-place, Glasgow.
1863. ‡Mitchell, C. Walker. Newcastle-on-Tyne.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1870. §Mitchell, John. Hall Foot, Clitheroe, Lancashire.
1868. ‡Mitchell, John, jun. Pole Park House, Dundee.
1862. *Mitchell, W. Stephen, M.A., LL.B. Caius College, Cambridge.

Year of
Election.

1879. ‡Mivart, St. George, M.D., F.R.S., F.L.S., F.Z.S., Professor of Biology in University College, Kensington. 71 Seymour-street, London, W.
1855. *Moffat, John, C.E. Ardrossan, Scotland.
1854. §§Moffat, Thomas, M.D., F.G.S., F.R.A.S., F.M.S. Hawarden, Chester.
1864. ‡Mogg, John Rees. High Littleton House, near Bristol.
1866. ‡Moggridge, Matthew, F.G.S. 8 Bina-gardens, South Kensington, London, S.W.
1861. ‡Molesworth, Rev. W. Nassau, M.A. Spotland, Rochdale.
Mollan, John, M.D. 8 Fitzwilliam-square North, Dublin.
1878. §Molloy, Constantine. 70 Lower Gardiner-street, Dublin.
1877. *Molloy, Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1852. ‡*Molony, William, LL.D. Carrickfergus.*
1865. §Molyneux, William, F.G.S. Branston Cottage, Burton-upon-Trent.
1860. ‡Monk, Rev. William, M.A., F.R.A.S. Wymington Rectory, Higham Ferrers, Northamptonshire.
1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
1872. §Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, London, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1881. §Moore, Henry. 4 Sheffield-terrace, Kensington, London, W.
Moore, John. 2 Meridian-place, Clifton, Bristol.
*Moore, John Carrick, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.
1866. *Moore, Thomas, F.L.S. Botanic Gardens, Chelsea, London, S.W.
1854. ‡Moore, Thomas John, Cor. M.Z.S. Free Public Museum, Liverpool.
1877. ‡Moore, W. F. The Friary, Plymouth.
1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.
1877. ‡Moore, William Vanderkemp. 15 Princess-square, Plymouth.
1871. ‡More, Alexander G., F.L.S., M.R.I.A. 3 Botanic View, Glasnevin, Dublin.
1881. §Morgan, Alfred. 97 Hartington-road, Sefton Park, Liverpool.
1873. ‡Morgan, Edward Delmar. 15 Rowland-gardens, London, W.
1833. Morgan, William, D.C.L. Oxon. Uckfield, Sussex.
1878. §§Morgan, William, Ph.D., F.C.S. Swansea.
1867. ‡Morison, William R. Dundee.
1863. ‡Morley, Samuel, M.P. 18 Wood-street, Cheapside, London, E.C.
1881. §Morrell, W. W. York City and County Bank, York.
1865. *Morrieson, Colonel Robert. Oriental Club, Hanover-square, London, W.
1880. §§Morris, Alfred Arthur Vennor. Wernolau, Cross Inn R.S.O., Carmarthenshire.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1881. §Morris, John, M.A., F.G.S. 15 Upper Gloucester-place, London, N.W.
1880. §§Morris, M. I. E. The Lodge, Penclawdd, near Swansea.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1876. §§Morris, Rev. S. S. O., M.A., R.N., F.C.S. H.M.S. 'Garnet,' S. Coast of America.
1874. †Morrison, G. J., C.E. 5 Victoria-street, Westminster, S.W.

Year of Election.

1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1879.§§Morrison, Dr. R. Milner. 20 Pentland-terrace, Edinburgh.
1865. §Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §Morton, George H., F.G.S. 122 London-road, Liverpool.
1858. *Morton, Henry Joseph. 4 Royal Crescent, Scarborough.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1857. ‡Moses, Marcus. 4 Westmoreland-street, Dublin.
Mosley, Sir Oswald, Bart., D.C.L. Rolleston Hall, Burton-upon-Trent, Staffordshire.
Moss, John. Otterspool, near Liverpool.
1878. *Moss, John Francis. Ranmoor, Sheffield.
1870. ‡Moss, John Miles, M.A. 2 Esplanade, Waterloo, Liverpool.
1876.§§Moss, Richard Jackson, F.C.S., M.R.I.A. 66 Kenilworth-square, Rathgar, Dublin.
1873. *Mosse, George Staley. Clarendon House, 16 Stanford-road, London, W.
1864. *Mosse, J. R. Public Works Department, Ceylon. (Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.)
1873. †Mossman, William. Woodhall, Calverley, Leeds.
1869. §Mott, Albert J., F.G.S. Crickley Hall, Gloucester.
1865. ‡Mott, Charles Grey. The Park, Birkenhead.
1866. §Mott, Frederick T., F.R.G.S. Birstall Hill, Leicester.
1862. *Mouat, Frederick John, M.D., Local Government Inspector. 12 Durham-villas, Campden Hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. Fulmodeston Rectory, Dereham, Norfolk.
1878. *Moulton, J. Fletcher, M.A., F.R.S. 74 Onslow-gardens, London, S.W.
1863. ‡Mounsey, Edward. Sunderland.
Mounsey, John. Sunderland.
1861. *Mountcastle, William Robert. Bridge Farm, Ellenbrook, near Manchester.
1877. ‡Mount-Edgcumbe, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.
1876. *Muir, John. 6 Park-gardens, Glasgow.
1874. ‡Muir, M. M. Pattison, F.R.S.E. Owens College, Manchester.
1876. §Muir, Thomas. High School, Glasgow.
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. 29 Regency-street, Westminster, S.W.
1871. *Muirhead, Henry, M.D. Bushy Hill, Cambuslang, Lanarkshire.
1876. *Muirhead, Robert Franklin, B.Sc. Meikle Cloak, Lochwinnoch, Renfrewshire.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1880. §Muller, Hugo M. 1 Grunangergasse, Vienna.
1866. ‡Mundella, The Right Hon. A. J., M.P., F.R.G.S. The Park, Nottingham.
1876.§§Munro, Donald, F.C.S. 97 Eglinton-street, Glasgow.
1872. *Munster, H. Sillwood Lodge, Brighton.
1864. ‡Murch, Jerom. Cranwells, Bath.
*_Murchison, John Henry. Surbiton Hill, Kingston._
1864. *Murchison, K. R. Brokehurst, East Grinstead.
1876. ‡Murdoch, James. Altony Albany, Girvan, N.B.
1855. ‡Murdoch, James B. Hamilton-place, Langside, Glasgow.
1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.

Year of Election.

1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1869. ‡Murray, Adam. 4 Westbourne-crescent, Hyde Park, London, W.
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1871. ‡Murray, John. 3 Clarendon-crescent, Edinburgh.
1859. ‡Murray, John, M.D. Forres, Scotland.
*Murray, John, C.E. Downlands, Sutton, Surrey.
‡Murray, Rev. John. Morton, near Thornhill, Dumfriesshire.
1872. ‡Murray, J. Jardine. 99 Montpellier-road, Brighton.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
1859. *Murton, James. Highfield, Silverdale, Carnforth.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1859. §Mylne, Robert William, F.R.S., F.G.S., F.S.A. 2 Middle Scotland-yard, London, S.W.

1842. Nadin, Joseph. Manchester.
1876. §Napier, James S. 9 Woodside-place, Glasgow.
1876. ‡Napier, John. Saughfield House, Hillhead, Glasgow.
*Napier, Captain Johnstone, C.E. Laverstock House, Salisbury.
1839. *Napier, The Right Hon. Sir Joseph, Bart., D.C.L., LL.D. 4 Merrion-square South, Dublin.
1872. ‡Nares, Captain Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 23 St. Philip's-road, Surbiton.
1866. ‡*Nash, Davyd W., F.S.A., F.L.S.* 10 *Imperial-square, Cheltenham.*
1850. *Nasmyth, James. Penshurst, Tunbridge.
1864. ‡Natal, The Right Rev. John William Colenso, D.D., Lord Bishop of. Natal.
1873. ‡Neill, Alexander Renton. Fieldhead House, Bradford, Yorkshire.
1873. ‡Neill, Archibald. Fieldhead House, Bradford, Yorkshire.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1865. ‡*Neilson, W. Montgomerie. Glasgow.*
1876. ‡Nelson, D. M. 48 Gordon-street, Glasgow.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1857. ‡Neville, John, C.E., M.R.I.A. Roden-place, Dundalk, Ireland.
1852. ‡Neville, Parke, C.E., M.R.I.A. 58 Pembroke-road, Dublin.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
Newall, Henry. Hare Hill, Littleborough, Lancashire.
*Newall, Robert Stirling, F.R.S., F.R.A.S. Ferndene, Gateshead-upon-Tyne.
1879. ‡Newbould, John. Sharrow Bank, Sheffield.
1866. *Newdigate, Albert L. 25 Craven-street, Charing Cross, London, W.C.
1876. ‡Newhaus, Albert. 1 Prince's-terrace, Glasgow.
1842. *Newman, Professor Francis William. 15 Arundel-crescent, Weston-super-Mare.
1863. *Newmarch, William, F.R.S. Brook House, Addlestone, Weybridge.
1866. *Newmarch, William Thomas. 1 Elms-road, Clapham Common, London, S.W.
1860. *Newton, Alfred, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalen College, Cambridge.
1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.

Year of Election.

1865. ‡Newton, Thomas Henry Goodwin. Clopton House, near Stratford-on-Avon.
1867. ‡Nicholl, Thomas. Dundee.
1875. ‡Nicholls, J. F. City Library, Bristol.
1866. ‡NICHOLSON, Sir CHARLES, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.
1838. *Nicholson, Cornelius, F.G.S., F.S.A. Ashleigh, Ventnor, Isle of Wight.
1861. *Nicholson, Edward. 88 Mosley-street, Manchester.
1871. §Nicholson, E. Chambers. Herne Hill, London, S.E.
1867. ‡NICHOLSON, HENRY ALLEYNE, M.D., D.Sc., F.G.S., Professor of Natural History in the University of St. Andrews, N.B.
1881. §Nicholson, William R. Clifton, York.
1867. ‡Nimmo, Dr. Matthew. Nethergate, Dundee.
1878. ‡Niven, Charles, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. Aberdeen.
1877. ‡Niven, James, M.A. King's College, Aberdeen.
‡Nixon, Randal C. J., M.A. Green Island, Belfast.
1863. *NOBLE, Captain ANDREW, F.R.S., F.R.A.S., F.C.S. Elswick Works, Newcastle-on-Tyne.
1880. §§Noble, John. Rossenstein, Thornhill-road, Croydon, Surrey.
1879. ‡Noble, T. S., F.G.S. Lendal, York.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1860. *Nolloth, Rear-Admiral Matthew S., R.N., F.R.G.S. United Service Club, S.W.; and 13 North-terrace, Camberwell, London, S.E.
1859. ‡Norfolk, Richard. Messrs. W. Rutherford and Co., 14 Canada Dock, Liverpool.
1868. Norgate, William. Newmarket-road, Norwich.
1863. §NORMAN, Rev. ALFRED MERLE, M.A. Burnmoor Rectory, Fence House, Co. Durham.
Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
1865. ‡NORRIS RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Corphwysfa, Llanrwst, North Wales.
1881. §North, Samuel William, M.R.C.S., F.G.S. 84 Micklegate, York.
1881. §North, William, B.A., F.C.S. 34 Bernard-street, Russell-square, London, W.C.
1869. ‡NORTHCOTE, The Right Hon. Sir STAFFORD H., Bart., K.G.C.B., M.P., F.R.S. Pynes, Exeter.
*NORTHWICK, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of. Norwich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1878. ‡Nugent, Edward, C.E. Seel's-buildings, Liverpool.

1878. ‡O'Brien, Murrough. 1 Willow-terrace, Blackrock, Co. Dublin.
O'Callaghan, George. Tallas, Co. Clare.
1878. ‡O'Carroll, Joseph F. 78 Rathgar-road, Dublin.
1878. ‡O'Conor Don, The, M.P. Clonalis, Castlerea, Ireland.
Odgers, Rev. William James. Savile House, Fitzjohn's-avenue, Hampstead, London, N.W.
1858. *ODLING, WILLIAM, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.

Year of Election.

1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.
1877. §Ogden, Joseph. 46 London-wall, London, E.C.
1876. ‡Ogilvie, Campbell P. Sizewell House, Lenton, Suffolk.
1859. ‡Ogilvie, Rev. C. W. Norman. Baldovan House, Dundee.
1874. §Ogilvie, Thomas Robertson. Bank Top, 3 Lyle-street, Greenock, N.B.
*Ogilvie-Forbes, George, M.D., Professor of the Institutes of Medicine in Marischal College, Aberdeen. Boyndlie, Fraserburgh, N.B.
1863. ‡*Ogilvy, G. R. Inverquharity, N.B.*
1863. ‡Ogilvy, Sir John, Bart. Inverquharity, N.B.
*Ogle, William, M.D., M.A. The Elms, Derby.
1859. ‡Ogston, Francis, M.D. 18 Adelphi-court, Aberdeen.
1837. ‡O'Hagan, John, M.A., Q.C. 22 Upper Fitzwilliam-street, Dublin.
1874. ‡O'Hagan, The Right Hon. Lord, M.R.I.A. 34 Rutland-square West, Dublin.
1862. ‡O'Kelly, Joseph, M.A., M.R.I.A. 14 Hume-street, Dublin.
1881. §Oldfield, Joseph. Lendal, York.
1853. §Oldham, James, C.E. Cottingham, near Hull.
1863. ‡Oliver, Daniel, F.R.S., Professor of Botany in University College, London. Royal Gardens, Kew, Surrey.
*Ommanney, Admiral Sir Erasmus, C.B., F.R.S., F.R.A.S., F.R.G.S. The Towers, Yarmouth, Isle of Wight.
1880. *Ommanney, Commander E. A., R.N., 44 Charing Cross, London, W.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1880. §§O'Reilly, J. P., C.E., Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1842. Ormerod, George Wareing, M.A., F.G.S. Brookbank, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham Hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1880. *Ormiston, Thomas, C.E. Ormsdale, Thurlow Park-road, Dulwich, S.E.
1835. Orpen, John H., LL.D., M.R.I.A. 58 Stephen's-green, Dublin.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1876. ‡*Orr, John B. Granville-terrace, Crosshill, Glasgow.*
1873. ‡Osborn, George. 47 Kingscross-street, Halifax.
1865. ‡Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.
*Osler, A. Follett, F.R.S. South Bank, Edgbaston, Birmingham.
1877. *Osler, Miss A. F. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. 50 Carpenter-road, Edgbaston, Birmingham.
1869. *Osler, Sidney F. 1 Pownall-gardens, Hounslow, near London.
1881. *Ottewell, Alfred D. 75 Grange-road, Middlesbrough.
1854. ‡Outram, Thomas. Greetland, near Halifax.
Overstone, Samuel Jones Lloyd, Lord, F.G.S. 2 Carlton-gardens, London, S.W.; and Wickham Park, Bromley.
1870. ‡Owen, Harold. The Brook Villa, Liverpool.
1857. ‡Owen, James H. Park House, Sandymount, Co. Dublin.
Owen, Richard, C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. M.R.S.E., Director of the Natural-History Department, British Museum. Sheen Lodge, Mortlake, Surrey, S.W.
1877. ‡Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.

Year of Election.

1875. ‡Paine, William Henry, M.D., F.G.S. Stroud, Gloucestershire.
1870. *Palgrave, R. H. Inglis. 11 Britannia-terrace, Great Yarmouth.
1873. ‡Palmer, George, M.P. The Acacias, Reading, Berks.
1866. §Palmer, H. 76 Goldsmith-street, Nottingham.
1878. *Palmer, Joseph Edward. Lyons Mills, Straffan Station, Dublin.
1866. §Palmer, William. Iron Foundry, Canal-street, Nottingham.
1872. *Palmer, W. R. Hawthorne, Rivercourt-road, Hammersmith, W.
Palmes, Rev. William Lindsay, M.A. Naburn Hall, York.
1880. *Parke, George Henry, F.L.S., F.G.S. Barrow-in-Furness, Lancashire.
1857. *Parker, Alexander, M.R.I.A. 59 William-street, Dublin.
1863. ‡Parker, Henry. Low Elswick, Newcastle-on-Tyne.
1863. ‡Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.
1874. ‡Parker, Henry R., LL.D. Methodist College, Belfast.
Parker, Richard. Dunscombe, Cork.
1865. *Parker, Walter Mantel. High-street, Alton, Hants.
Parker, Rev. William. Saham, Norfolk.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling. 6 St. Mary's-row, Birmingham.
1864. ‡Parkes, William. 23 Abingdon-street, Westminster, S.W.
1879. §Parkin, William, F.S.S. The Mount, Sheffield.
1859. ‡Parkinson, Robert, Ph.D. West View, Toller-lane, Bradford, Yorkshire.
1841. Parnell, Edward A., F.C.S. Ashley Villa, Swansea.
1862. *Parnell, John, M.A. 1 The Common, Upper Clapton, London, E.
Parnell, Richard, M.D., F.R.S.E. Gattonside Villa, Melrose, N.B.
1877. ‡Parson, T. Edgcumbe. 36 Torrington-place, Plymouth.
1865. *Parsons, Charles Thomas. Norfolk-road, Edgbaston, Birmingham.
1878. ‡Parsons, Hon. C. A. 10 Connaught-place, London, W.
1878. ‡Parsons, Hon. and Rev. R. C. 10 Connaught-place, London, W.
1875. ‡Pass, Alfred C. Rushmere House, Durdham Down, Bristol.
1881. §Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1861. ‡Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
1871. *Patterson, A. Henry. 3 New-square, Lincoln's Inn, London, W.C.
1863. ‡Patterson, H. L. Scott's House, near Newcastle-on-Tyne.
1867. ‡Patterson, James. Kinnettles, Dundee.
1876. §Patterson, T. L. Belmont, Margaret-street, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1863. ‡Pattinson, John, F.C.S. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-upon-Tyne.
1867. §Pattison, Samuel Rowles, F.G.S. 50 Lombard-street, London, E.C.
1864. ‡Pattison, Dr. T. H. London-street, Edinburgh.
1879. *Patzer, F. R. Stoke-on-Trent.
1863. ‡Paul, Benjamin H., Ph.D. 1 Victoria-street, Westminster, S.W.
1863. ‡Pavy, Frederick William, M.D., F.R.S., Lecturer on Physiology and Comparative Anatomy and Zoology at Guy's Hospital. 35 Grosvenor-street, London, W.
1864. ‡Payne, Edward Turner. 3 Sydney-place, Bath.
1881. §Payne, J. Buxton. 15 Mosley-street, Newcastle-on-Tyne.
1877. ‡Payne, J. C. Charles. 5 Princess-gardens, The Plains, Belfast.
1881. §Payne, Mrs. 5 Princess-gardens, The Plains, Belfast.
1866. ‡Payne, Dr. Joseph F. 78 Wimpole-street, London, W.
1876. ‡Peace, G. H. Morton Grange, Eccles, near Manchester.

Year of Election.

1879. ‡Peace, William K. Western Bank, Sheffield.
1847. ‡PEACH, CHARLES W., Pres. R.P.S. Edin., A.L.S. 30 Haddington-place, Leith-walk, Edinburgh.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C.
1881. *Pearce, Horace, F.L.S., F.G.S. The Limes, Stourbridge.
1876. ‡Pearce, W. Elmpark House, Govan, Glasgow.
*Pearsall, Thomas John, F.C.S. Birkbeck Literary and Scientific Institution, Southampton-buildings, Chancery-lane, London, W.C.
1881. §Pearse, Richard Seward. Southampton.
1881. §Pearson, John. Glentworth House, The Mount, York.
1872. *Pearson, Joseph. Lern Side Works, Nottingham.
1881. §Pearson, Richard. 23 Bootham, York.
1870. ‡Pearson, Rev. Samuel. 48 Prince's-road, Liverpool.
1863. §Pease, H. F. Brinkburn, Darlington.
1863. *Pease, Joseph W., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-on-Tyne.
1858. *Pease, Thomas, F.G.S. Cote Bank, Westbury-on-Trym, near Bristol.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F.L.S., F.R.G.S. Harecroft House, Wisbech, Cambridgeshire.
*Peckover, Algernon, F.L.S. Sibald's Holme, Wisbech, Cambridgeshire.
1878. *Peek, William. St. Clair, Hayward's Heath, Sussex.
*Peel, George. Soho Iron Works, Manchester.
1873. ‡Peel, Thomas. 9 Hampton-place, Bradford, Yorkshire.
1881. §Peggs, J. Wallace. 21 Queen Anne's-gate, London, S.W.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1861. *Peiser, John. Barnfield House, 491 Oxford-street, Manchester.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, London, W.C.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, John, M.P. 18 Arlington-street, London, S.W.
1868. ‡Pendergast, Thomas. Lancefield, Cheltenham.
1856. §PENGELLY, WILLIAM, F.R.S., F.G.S. Lamorna, Torquay.
1881. §Penty, W. G. Melbourne-street, York.
1875. ‡Percival, Rev. J., M.A., LL.D., President of Trinity College, Oxford.
1845. ‡PERCY, JOHN, M.D., F.R.S., F.G.S., 1 Gloucester-crescent, Hyde Park, London, W.
*Perigal, Frederick. Thatched House Club, St. James's-street, London, S.W.
1868. *PERKIN, WILLIAM HENRY, F.R.S., F.C.S. The Chestnuts, Sudbury, Harrow.
1877. §Perkins, Loftus. 140 Abbey-road, Kilburn, London, N.W.
Perkins, Rev. R. B., D.C.L. Wotton-under-Edge, Gloucestershire.
1864. *Perkins, V. R. 54 Gloucester-street, London, S.W.
Perry, The Right Rev. Charles, M.A., D.D. 32 Avenue-road, Regent's Park, London, N.W.
1879. ‡Perry, James. Roscommon.
1874. *PERRY, JOHN. 14 Talgarth-road, West Kensington, London, S.W.
*Perry, Rev. S. G. F., M.A. Tottington Vicarage, near Bury.
1870. *PERRY, Rev. S. J., F.R.S., F.R.A.S., F.M.S. Stonyhurst College Observatory, Whalley, Blackburn.
1861. *Petrie, John. South-street, Rochdale.
Peyton, Abel. Oakhurst, Edgbaston, Birmingham.

Year of
Election.

1871. *Peyton, John E. H., F.R.A.S., F.G.S. 1 Uplands, St. Leonard's-on-Sea.
1882. §Pfoundes, Charles, F.R.G.S., Spring Gardens, London, S.W.
1867. ‡PHAYRE, Lieut.-General Sir ARTHUR, K.C.S.I., C.B. Athenæum Club, Pall Mall, London, S.W.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. 35 Church-street, Manchester.
Philips, Robert N. The Park, Manchester.
1877. §Philips, T. Wishart. 33 Woodstock-road, Poplar, London, E.
1863. ‡Philipson, Dr. 1 Savile-row, Newcastle-on-Tyne.
1862. ‡Phillips, Rev. George, D.D. Queen's College, Cambridge.
1872. ‡PHILLIPS, J. ARTHUR, F.R.S. 18 Fopstone-road, Earl's Court-road, London, S.W.
1880. §Phillips, John H., Hon. Sec. Philosophical and Archæological Society, Scarborough.
1881. §Phillips, William. 9 Bootham-terrace, York.
1868. ‡Phipson, R. M., F.S.A. Surrey-street, Norwich.
1868. ‡PHIPSON, T. L., Ph.D., F.C.S. 4 The Cedars, Putney, Surrey, S.W.
1864. ‡Pickering, William. Oak View, Clevedon.
1870. ‡Picton, J. Allanson, F.S.A. Sandyknowe, Wavertree, Liverpool.
1870. ‡*Pigot, Rev. E. V. Malpas, Cheshire.*
1871. ‡Pigot, Thomas F., C.E., M.R.I.A. Royal College of Science, Dublin.
*Pike, Ebenezer. Besborough, Cork.
1865. ‡PIKE, L. OWEN. 25 Carlton-villas, Maida-vale, London, W.
1873. ‡Pike, W. H. 4 The Grove, Highgate, London, N.
1857. ‡Pilkington, Henry M., M.A., Q.C. 45 Upper Mount-street, Dublin.
1863. *PIM, Captain BEDFORD C. T., R.N., F.R.G.S. Leaside, Kingswood-road, Upper Norwood, London, S.E.
Pim, George, M.R.I.A. Brenanstown, Cabinteely, Co. Dublin.
Pim, Jonathan. Harold's Cross, Dublin.
1877. §Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡Pirie, Rev. G. Queen's College, Cambridge.
1859. ‡Pirrie, William, M.D., LL.D. 238 Union-street West, Aberdeen.
1866. ‡Pitcairn, David. Dudhope House, Dundee.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1868. ‡PITT-RIVERS, Major-General A. H. L., F.R.S., F.G.S., F.R.G.S., F.S.A. 4 Grosvenor-gardens, London, S.W.
1872. ‡Plant, Mrs. H. W. 28 Evington-street, Leicester.
1869. §PLANT, JAMES, F.G.S. 40 West-terrace, West-street, Leicester.
1865. ‡Plant, Thomas L. Camp Hill, and 33 Union-street, Birmingham.
1842. PLAYFAIR, The Right Hon. LYON, C.B., Ph.D., LL.D., M.P., F.R.S. L. & E., F.C.S. 68 Onslow-gardens, South Kensington, London, S.W.
1867. ‡PLAYFAIR, Lieut.-Colonel R. L., H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, London, S.W.)
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *POCHIN, HENRY DAVIS, F.C.S. Bodnant Hall, near Conway.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1846. ‡POLE, WILLIAM, Mus. Doc., F.R.S., M.I.C.E. Athenæum Club, Pall Mall, London, S.W.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.

Year of Election.

Pollock, A. 52 Upper Sackville-street, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1854. ‡Poole, Braithwaite. Birkenhead.
1868. ‡Portal, Wyndham S. Malsanger, Basingstoke.
1874. ‡Porter, Rev. J. Leslie, D.D., LL.D., President of Queen's College, Belfast.
1866. §Porter, Robert. Montpelier Cottage, Beeston, Nottingham.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
*Potter, Edmund, F.R.S. Camfield-place, Hatfield, Herts.
1857. *Pounden, Captain Lonsdale, F.R.G.S. Junior United Service Club, St. James's-square, London, S.W.; and Brownswood House, Enniscorthy, Co. Wexford.
1873. *Powell, Francis S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1881. §Powell, G. S. Baden, M.A., F.R.A.S. 8 St. George's-place, Hyde Park Corner, London, S.W.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1857. ‡Power, Sir James, Bart. Edermine, Enniscorthy, Ireland.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuk, Uddingston, Scotland.
1869. *Preece, William Henry, F.R.S. Gothic Lodge, Wimbledon Common, London, S.W.
Prest, The Venerable Archdeacon Edward. The College, Durham.
1881. §Preston, Rev. Thomas Arthur, M.A. The Green, Marlborough.
*Prestwich, Joseph, M.A., F.R.S., F.G.S., F.C.S., Professor of Geology in the University of Oxford. 34 Broad-street, Oxford; and Shoreham, near Sevenoaks.
1871. ‡Price, Astley Paston. 47 Lincoln's-Inn-Fields, London, W.C.
1856. *Price, Rev. Bartholomew, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford, 11 St. Giles's, Oxford.
1872. ‡Price, David S., Ph.D. 26 Great George-street, Westminster, S.W.
Price, J. T. Neath Abbey, Glamorganshire.
1881. §Price, Peter. Crockherbtown, Cardiff.
1875. *Price, Rees. 2 Blythe-villas, West Kensington Park, London, W.
1870. *Price, Major W. E., F.G.S. Hillfield, Gloucester.
1875. *Price, William Philip. Tibberton Court, Gloucester.
1876. ‡Priestley, John. 174 Lloyd-street, Greenheys, Manchester.
1875. ‡Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1835. *Pritchard, Andrew, F.R.S.E. 87 St. Paul's-road, Canonbury, London, N.
1846. *Pritchard, Rev. Charles, M.A., F.R.S., F.G.S., F.R.A.S., Professor of Astronomy in the University of Oxford. 8 Keble-terrace, Oxford.
1876. *Pritchard, Urban, M.D., F.R.C.S. 3 George-street, Hanover-square, London, W.
1872. ‡Pritchard, Rev. W. Gee. Brignal Rectory, Barnard Castle, Co. Durham.
1881. §Procter, John William. 23 St. Paul's-square, York.
1863. ‡Proctor, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, Thomas. Elmsdale House, Clifton Down, Bristol.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.

Year of Election.

1863. *Prosser, Thomas. 25 Harrison-place, Newcastle-on-Tyne.
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1879. *Prouse, Oswald Milton, F.G.S., F.R.G.S. 4 Cambridge-villas, Richmond Park-road, Kingston-on-Thames.
1865. ‡Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.
1872. *Pryor, M. Robert. Weston Manor, Stevenage, Herts.
1871. *Puckle, Thomas John. Woodcote-grove, Carshalton, Surrey.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Robert. Tayside, Perth.
1842. *Pumphrey, Charles. Southfield, King's Norton, near Birmingham.
Punnet, Rev. John, M.A., F.C.P.S. St. Earth, Cornwall.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1860. ‡PURDY, FREDERICK, F.S.S., Principal of the Statistical Department of the Poor Law Board, Whitehall, London. Victoria-road, Kensington, London, W.
1881. §Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1874. ‡PURSER, FREDERICK, M.A. Rathmines, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., M.R.I.A. Queen's College, Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1868. ‡PYE-SMITH, P. H., M.D. 56 Harley-street, W.; and Guy's Hospital, London, S.E.
1879. §§Pye-Smith, R. J. 7 Surrey-street, Sheffield.
1861. *Pyne, Joseph John. The Willows, Albert-road, Southport.

1870. ‡Rabbits, W. T. Forest Hill, London, S.E.
1860. ‡RADCLIFFE, CHARLES BLAND, M.D. 25 Cavendish-square, London, W.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1877. ‡Radford, George D. Mannamead, Plymouth.
1879. ‡Radford, R. Heber, M.I.C.E. Wood Bank, Pitsmoor, Sheffield.
*Radford, William, M.D. Sidmount, Sidmouth.
1855. *Radstock, Lord. 70 Portland-place, London, W.
1878. ‡Rae, John, M.D., LL.D., F.R.S. 2 Addison-gardens South, Kensington, London, W.
1854. ‡Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.
1870. ‡*Raffles, William Winter. Sunnyside, Prince's Park, Liverpool.*
1864. ‡Rainey, James T. St. George's Lodge, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1863. ‡RAMSAY, ALEXANDER, F.G.S. Kilmorey Lodge, 6 Kent-gardens, Ealing, W.
1845. ‡RAMSAY, Sir ANDREW CROMBIE, LL.D., F.R.S., F.G.S. 15 Cromwell-crescent, South Kensington, London, S.W.
1867. ‡*Ramsay, James, jun. Dundee.*
1861. ‡Ramsay, John, M.P. Kildalton, Argyleshire.
1867. *Ramsay, W. F., M.D. 39 Hammersmith-road, West Kensington, London, W.
1876. ‡RAMSAY, WILLIAM, Ph.D., Professor of Chemistry in University College, Bristol.
1873. *Ramsden, William. Bracken Hall, Great Horton, Bradford, Yorkshire.
1835. *Rance, Henry (Solicitor). Cambridge.
1869. *Rance, H. W. Henniker, LL.M. 10 Castletown-road, West Kensington, London, S.W.
1860. ‡Randall, Thomas. Grandepoint House, Oxford.
1865. ‡Randel, J. 50 Vittoria-street, Birmingham.

Year of Election.

Ranelagh, The Right Hon. Lord. 7 New Burlington-street, Regent-street, London, W.
1868. *Ransom, Edwin, F.R.G.S. Bedford.
1863. §Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡Ransome, Arthur, M.A. Bowdon, Manchester.
Ransome, Thomas. 34 Princess-street, Manchester.
1872. *Ranyard, Arthur Cowper, F.R.A.S. 25 Old-square, Lincoln's Inn, London, W.C.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London. N.W.
Ratcliff, Colonel Charles, F.L.S., F.G.S., F.S.A., F.R.G.S. Wyddrington, Edgbaston, Birmingham.
1864. ‡Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.
1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.
1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.
1870. §Rathbone, R. R. Beechwood House, Liverpool.
1863. ‡Rattray, W. St. Clement's Chemical Works, Aberdeen.
1874. ‡Ravenstein, E. G., F.R.G.S. 10 Lorn-road, Brixton, London, S.W.
Rawdon, William Frederick, M.D. Bootham, York.
1870. ‡Rawlins, G. W. The Hollies, Rainhall, Liverpool.
1866. *Rawlinson, Rev. Canon George, M.A., Camden Professor of Ancient History in the University of Oxford. The Oaks, Precincts, Canterbury.
1855. *Rawlinson, Major-General Sir Henry C., K.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1875. §Rawson, Sir Rawson W., K.C.M.G., C.B., F.R.G.S. 68 Cornwall-gardens, Queen's-gate, London, S.W.
1868. *Rayleigh, The Right Hon. Lord, M.A., F.R.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. 5 Salisbury-villas, Cambridge.
1870. ‡Rayner, Joseph (Town Clerk). Liverpool.
1865. ‡Read, William. Albion House, Epworth, Rawtry.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.
1870. §Reade, Thomas Mellard, C.E., F.G.S. Blundellsands, Liverpool.
1862. *Readwin, Thomas Allison, M.R.I.A., F.G.S. 8 Bloomsbury-square, London, W.C.
1852. *Redfern, Professor Peter, M.D. 4 Lower-crescent, Belfast.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1863. ‡Redmayne, R. R. 12 Victoria-terrace, Newcastle-on-Tyne.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. ‡Reed, Sir Edward J., K.C.B., M.P., F.R.S. 74 Gloucester-road, South Kensington, London, W.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1878. §Reichel, The Ven. Archdeacon, D.D. The Archdeaconry, Trim, Ireland.
1881. §Reid, Arthur S., B.A., F.G.S. 12 Bridge-street, Canterbury.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1874. ‡*Reid, Robert, M.A.* 35 *Dublin-road, Belfast.*
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1881. §Reid, William. 19½ Blake-street, York.
1875. §Reinold, A. W., M.A., Professor of Physical Science. Royal Naval College, Greenwich, S.E.
1863. §Renals, E. 'Nottingham Express' Office, Nottingham.
1863. ‡Rendel, G. Benwell, Newcastle-on-Tyne.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.

Year of
Election.

1871. ‡REYNOLDS, JAMES EMERSON, M.A., F.R.S., F.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1870. *REYNOLDS, OSBORNE, M.A., F.R.S., Professor of Engineering in Owens College, Manchester. Fallowfield, Manchester.
1858. §REYNOLDS, RICHARD, F.C.S. 13 Briggate, Leeds.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Via Stimmate, 15, Modena, Italy.
1863. ‡RICHARDSON, BENJAMIN WARD, M.A., M.D., F.R.S. 12 Hinde-street, Manchester-square, London, W.
1861. ‡Richardson, Charles. 10 Berkeley-square, Bristol.
1869. *Richardson, Charles. 4 Northumberland-avenue, Putney, S.W.
1863. *Richardson, Edward. 6 Stanley-terrace, Gosforth, Newcastle-on-Tyne.
1868. *Richardson, George. 4 Edward-street, Werneth, Oldham.
1870. ‡*Richardson, J. H. 3 Arundel-terrace, Cork.*
1870. ‡Richardson, Ralph. 16 Coates-crescent, Edinburgh.
Richardson, Thomas. Montpelier-hill, Dublin.
1881. §Richardson, W. B. Elm Bank, York.
1861. ‡Richardson, William. 4 Edward-street, Werneth, Oldham.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1863. ‡Richter, Otto, Ph.D. 6 Derby-terrace, Glasgow
1870. ‡*Rickards, Dr. 36 Upper Parliament-street, Liverpool.*
1868. §RICKETTS, CHARLES, M.D., F.G.S. 22 Argyle-street, Birkenhead.
1877. ‡Ricketts, James, M.D. St. Helen's, Lancashire.
*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1861. *Riddell, Henry B. Whitefield House, Rothbury, Morpeth.
1872. ‡Ridge, James. 98 Queen's-road, Brighton.
1862. ‡Ridgway, Henry Ackroyd, B.A. Bank Field, Halifax.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1863. *Rigby, Samuel. Bruche Hall, Warrington.
1881. §Rigg, Arthur. 79 Warrington-crescent, London, W.
1873. ‡Ripley, Edward. Acacia, Apperley, near Leeds.
1873. ‡Ripley, Sir Henry William, Bart. Acacia, Apperley, near Leeds.
*RIPON, The Most Hon. the Marquis of, K.G., D.C.L., F.R.S., F.L.S., F.R.G.S. 1 Carlton-gardens, London, S.W.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1855. ‡Ritchie, Robert, C.E. 14 Hill-street, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1869. *Rivington, John. Babbicombe, near Torquay.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *ROBBINS, JOHN, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
1878. ‡Roberts, Charles, F.R.C.S. 2 Bolton-row, London, W.
1859. ‡Roberts, George Christopher. Hull.
1870. *ROBERTS, ISAAC, F.G.S. Kennessee, Maghull, Lancashire.
1857. ‡Roberts, Michael, M.A. Trinity College, Dublin.
1881. §Roberts, R. D. Clare College, Cambridge.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1868. §ROBERTS, W. CHANDLER, F.R.S., F.G.S., F.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal School of Mines. Royal Mint, London, E.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.

Year of
Election.

1876. ‡*Robertson, Andrew Carrick. Woodend House, Helensburgh, N.B.*
1867.§§Robertson, David. Union Grove, Dundee.
1871. ‡Robertson, George, C.E., F.R.S.E. 47 Albany-street, Edinburgh.
1870. *Robertson, John. 4 Albert-road, Southport.
1876. ‡Robertson, R. A. Newthorn, Ayton-road, Pollokshields, Glasgow.
1866. ‡ROBERTSON, WILLIAM TINDAL, M.D. Nottingham.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Tartaragham Glebe, Loughgall, Ireland.
1859. ‡Robinson, Hardy. 156 Union-street, Aberdeen.
*Robinson, H. Oliver. 34 Bishopsgate-street, London, E.C.
1873. §Robinson, Hugh. 82 Donegall-street, Belfast.
1861. ‡ROBINSON, JOHN, C.E. Atlas Works, Manchester.
1863. ‡Robinson, J. H. Cumberland-row, Newcastle-on-Tyne.
1878. ‡Robinson, John L., C.E. 198 Great Brunswick-street, Dublin.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1881. §Robinson, Richard Atkinson. 195 Brompton-road, London, S.W.
1875. *Robinson, Robert, C.E., F.G.S. 2 West-terrace, Darlington.
1860. ‡Robinson, Admiral Sir Robert Spencer, K.C.B., F.R.S. 61 Eaton-place, London, S.W.
ROBINSON, Rev. THOMAS ROMNEY, D.D., F.R.S., F.R.A.S., Hon. F.R.S.E., M.R.I.A., Director of the Armagh Observatory. Armagh.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1870. ‡Robinson, William. 40 Smithdown-road, Liverpool.
1870. *Robson, E. R. 41 Parliament-street, Westminster, S.W.
1876. ‡Robson, Hazleton R. 14 Royal-crescent West, Glasgow.
1855. ‡Robson, Neil, C.E. 127 St. Vincent-street, Glasgow.
1872. *Robson, William. Marchholm, Gillsland-road, Merchiston, Edinburgh.
1872. §RODWELL, GEORGE F., F.R.A.S., F.C.S. Marlborough College, Wiltshire.
1866. ‡Roe, Thomas. Grove-villas, Sitchurch.
1860. ‡ROGERS, JAMES E. THOROLD, M.P., Professor of Economic Science and Statistics in King's College, London. Beaumont-street, Oxford.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1869. *Rogers, Nathaniel, M.D. 87 South-street, Exeter.
1870. ‡Rogers, T. L., M.D. Rainhill, Liverpool.
1876. §ROLLIT, A. K., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1876. ‡Romanes, George John, M.A., F.R.S., F.L.S. 18 Cornwall-terrace, Regent's Park, London, N.W.
1846. ‡Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. *Roper, Freeman Clarke Samuel, F.L.S., F.G.S. Palgrave House, Eastbourne.
1881. §Roper, W. O. Southfield, Lancaster.
1855. *ROSCOE, HENRY ENFIELD, B.A., Ph.D., LL.D., F.R.S., F.C.S., Professor of Chemistry in Owens College, Manchester.
1863. ‡Roseby, John. Haverholm House, Brigg, Lincolnshire.
1874. ‡Ross, Alexander Milton, M.A., M.D., F.G.S. Toronto, Canada.
1857. ‡Ross, David, LL.D. 32 Nelson-street, Dublin.
1880. §Ross, Captain G. E. A., F.R.G.S. Forfar House, Cromwell-road, London, S.W.
1872. ‡Ross, James, M.D. Tenterfield House, Waterfoot, near Manchester.
1859. *Ross, Rev. James Coulman. Baldon Vicarage, Oxford.
1874. †Ross, Rev. William. Chapelhill Manse, Rothesay, Scotland.

Year of Election.

1880. §Ross, Colonel William Alexander. Acton House, Acton, London, W.

1869. *Rosse, The Right Hon. the Earl of, B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.

1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.

1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.

1861. ‡Routh, Edward J., M.A., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.

1881. §Routh, Rev. William, M.A. Clifton Green, York.

1872. *Row, A. V. Nursing Observatory, Daba-gardens, Vizagapatam, India. (Care of Messrs. King & Co., 45 Pall Mall, London, S.W.)

1861. ‡Rowan, David. Elliot-street, Glasgow.

1881. §Rowe, Rev. G. Lord Mayor's Walk, York.

1865. §Rowe, Rev. John. Load Vicarage, Langport, Somerset.

1877. §Rowe, J. Brooking, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.

1881. §Rowe, R. C., M.A., Professor of Pure Mathematics in University College, London. University College, London, W.C.

1855. *Rowney, Thomas H., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway. Salerno, Salthill, Galway.

1881. *Rowntree, Joseph. 19 Bootham, York.

1881. *Rowntree, J. S. The Mount, York.

1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.

1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.

1861. *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.

1875. ‡Rücker, A. W., M.A., Professor of Mathematics and Physics in the Yorkshire College, Leeds.

1869. §Rudler, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.

1873. ‡Rushforth, Joseph. 43 Ash-grove, Horton-lane, Bradford, Yorkshire.

1847. ‡Ruskin, John, M.A., F.G.S., Slade Professor of Fine Arts in the University of Oxford. Corpus Christi College, Oxford.

1875. *Russell, The Hon. F. A. R. Pembroke Lodge, Richmond Park, Surrey.

1876. *Russell, George. 103 Blenheim-crescent, Notting Hill, London, W.

1865. ‡Russell, James, M.D. 91 Newhall-street, Birmingham.

Russell, John. 39 Mountjoy-square, Dublin.

Russell, John Scott, M.A., F.R.S. L. & E. Sydenham, S.E.

1852. **Russell, Norman Scott, Sydenham.*

1876. §Russell, R., C.E., F.G.S. 1 Sea View, St. Bees, Carnforth.

1862. §Russell, W. H. L., A.B., F.R.S. 5 The Grove, Highgate, London, N.

1852. *Russell, William J., Ph.D., F.R.S., F.C.S., Professor of Chemistry in St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.

1875. ‡*Rutherford, David Greig. Surrey House, Forest Hill, London, S.E.*

1871. §Rutherford, William, M.D., F.R.S., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.

1881. §Rutson, Albert. Newby Wiske, Thirsk.

Rutson, William. Newby Wiske, Northallerton, Yorkshire.

1879. ‡Ruxton, Captain Fitzherbert, R.N. 41 Cromwell-gardens, London, S.W.

1875. ‡Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, London, E.C.

1874. §§Rye, E. C., F.Z.S., Librarian R.G.S. Royal Geographical Society, 1 Savile-row, London, W.

Year of Election.

1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *RYLANDS, THOMAS GLAZEBROOK, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

SABINE, General Sir EDWARD, K.C.B., R.A., LL.D., D.C.L., F.R.S., F.R.A.S., F.L.S., F.R.G.S. 13 Ashley-place, Westminster, S.W.
1871. ‡Sadler, Samuel Champernowne. Purton Court, Purton, near Swindon, Wiltshire.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1880. §§Sakurai, J. 96 Camden-street, London, N.W.
1881. §Salkeld, William. 4 Paradise-terrace, Darlington.
1857. ‡SALMON, Rev. GEORGE, D.D., D.C.L., F.R.S., Regius Professor of Divinity in the University of Dublin. Trinity College, Dublin.
1873. *Salomons, Sir David, Bart. Broomhill, Tunbridge Wells.
1872. ‡SALVIN, OSBERT, M.A., F.R.S., F.L.S. Brookland Avenue, Cambridge.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1861. *Sandeman, Archibald, M.A. Tulloch, Perth.
1876. ‡Sandeman, David. Woodlands, Lenzie, Glasgow.
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1872. ‡Sanders, Mrs. 8 Powis-square, Brighton.
1872. ‡SANDERSON, J. S. BURDON, M.D., LL.D., F.R.S., Professor of Physiology in University College, London. 26 Gordon-square, London, W.C.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1864. ‡Sandford, William. 9 Springfield-place, Bath.
1854. ‡Sandon, The Right Hon. Lord, M.P. 39 Gloucester-square, London, W.
1873. ‡Sands, T. C. 24 Spring-gardens, Bradford, Yorkshire.
1865. ‡*Sargant, W. L. Edmund-street, Birmingham.*
1868. ‡Saunders, A., C.E. King's Lynn.
1881. §Saunders, Howard, F.L.S., F.Z.S. 7 Radnor-place, London, W.
1846. ‡SAUNDERS, TRELAWNEY W. India Office, London, S.W.
1864. ‡Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.
1860. *Saunders, William. 3 Gladstone-terrace, Brighton.
1871. §Savage, W. D. Ellerslie House, Brighton.
1872. *Sawyer, George David. 55 Buckingham-place, Brighton.
1868. ‡Sawyer, John Robert. Grove-terrace, Thorpe Hamlet, Norwich.
1868. §Schacht, G. F. 7 Regent's-place, Clifton, Bristol.
1879. *Schäfer, E. A., F.R.S., M.R.C.S., Assistant Professor of Physiology in University College, London. Boreham Wood, Elstree, Herts.
*Schemmann, J. C. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1874. §Scholefield, Henry. Windsor-crescent, Newcastle-on-Tyne.
1876. ‡Schuman, Sigismond. 7 Royal Bank-place, Glasgow.
SCHUNCK, EDWARD, F.R.S., F.C.S. Oaklands, Kersall Moor, Manchester.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S., Professor of Applied Mathematics in Owens College, Manchester.
1861. *Schwabe, Edmund Salis. Ryecroft House, Cheetham Hill, Manchester.

Year of Election.

1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., Sec. Zool. Soc. 11 Hanover-square, London, W.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1881. §Scott, Alexander, B.A., B.Sc. Trinity College, Cambridge.
1878.§§Scott, Arthur William. St. David's College, Lampeter.
1881. §Scott, Miss Charlotte A. Girton College, Cambridge.
1876. ‡Scott, Mr. Bailie. Glasgow.
1871. ‡Scott, Rev. C. G. 12 Pilrig-street, Edinburgh.
1872. ‡Scott, Major-General H. Y. D., C.B., R.E., F.R.S. Sunnyside, Ealing, W.
1871. ‡*Scott, James S. T. Monkrigg, Haddingtonshire.*
1857. *SCOTT, ROBERT H., M.A., F.R.S., F.G.S., F.M.S., Secretary to the Council of the Meteorological Office. 6 Elm Park-gardens, London, S.W.
1861. §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.
1874. ‡Scott, Rev. Robinson, D.D. Methodist College, Belfast.
1864. ‡*Scott, Wentworth Lascelles. Wolverhampton.*
1858. ‡Scott, William. Holbeck, near Leeds.
1869. ‡Scott, William Bower. Chudleigh, Devon.
1881. *Scrivener, A. P. Weston Turvill, Tring.
1859. ‡Seaton, John Love. Hull.
1877. ‡*Seaton, Robert Cooper, B.A. Dulwich College, Dulwich, Surrey, S.E.*
1880.§§Sedgwick, Adam, B.A. Trinity College, Cambridge.
1880. §Seebohm, Henry, F.L.S., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.
1861. *SEELEY, HARRY GOVIER, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geography in King's College, London. 14 Oppidans road, Primrose Hill, London, N.W.
1855. ‡Seligman, H. L. 135 Buchanan-street, Glasgow.
1879. §Selim, Adolphus. 21 Mincing-lane, London, E.C.
1873. ‡Semple, R. H., M.D. 8 Torrington-square, London, W.C.
1858. *Senior, George, F.S.S. Rosehill, Dodworth, near Barnsley.
1870. *Sephton, Rev. J. 92 Huskisson-street, Liverpool.
1875. §Seville, Thomas. Blythe House, Southport, Lancashire.
1873. ‡Sewell, Rev. E., M.A., F.G.S., F.R.G.S. Ilkley College, near Leeds
1868. ‡Sewell, Philip E. Catton, Norwich.
1861. **Seymour, Henry D. 209 Piccadilly, London, W.*
*Shaen, William. 15 Upper Phillimore-gardens, Kensington, London, W.
1871. *Shand, James. Fullbrooks, Worcester Park, Surrey.
1867. §Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. §Shann, George, M.D. Petergate, York.
1869. §Shapter, Dr. Lewis, LL.D. The Barnfield, Exeter.
1878. ‡SHARP, DAVID, M.B. Thornhill, Dumfriesshire.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1861. ‡SHARP, SAMUEL, F.G.S., F.S.A. Great Harrowden Hall, near Wellingborough.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1881. *Shaw, H. S. Hele, M.A. 2 Pembroke-vale, Clifton, Bristol.
1870. ‡Shaw, John. 24 Great George-place, Liverpool.

Year of
Election.

1845. ‡Shaw, John, M.D., F.L.S., F.G.S. Hop House, Boston, Lincolnshire.
1878. ‡Shelford, W., C.E. 35A Great George-street, Westminster, S.W.
1881. §Shenstone, W. A. Clifton College, Bristol.
1839. Shepard, John. 4 Highfield-place, Manningham, Bradford, Yorkshire.
1863. ‡Shepherd, A. B. 49 Seymour-street, Portman-square, London, W.
1870. §Shepherd, Joseph. 29 Everton-crescent, Liverpool.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1880. §Shida, R. 1 St. James's-place, Hillhead, Glasgow.
1866. ‡Shilton, Samuel Richard Parr. Sneinton House, Nottingham.
1867. ‡Shinn, William C. 4 Varden's-road, Clapham Junction, Surrey, S.W.
1870. *Shoolbred, James N., C.E., F.G.S. 3 Westminster-chambers, London, S.W.
1875. ‡Shore, Thomas W., F.C.S. Hartley Institution, Southampton.
1881. §Shuter, James L. Lawn House, Tufnell Park, London, N.
1861. *Sidebotham, Joseph. The Beeches, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. The Beeches, Bowdon, Cheshire.
1873. ‡Sidgwick, R. H. The Raikes, Skipton.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 12 Queen Anne's-gate, Westminster, S.W.
1856. *Siemens, C. William, D.C.L., LL.D., F.R.S., F.C.S., M.I.C.E. (President Elect.) 12 Queen Anne's-gate, Westminster, S.W.
1878. ‡Sigerson, Professor George, M.D., F.L.S., M.R.I.A. 3 Clare-street, Dublin.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1865. ‡Simkiss, T. M. Wolverhampton.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1874. §Simms, William. The Linen Hall, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, London, W.
1847. ‡Simon, John, C.B., D.C.L., F.R.S., F.R.C.S., Surgeon to St. Thomas's Hospital. 40 Kensington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.
1871. *Simpson, Alexander R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Maykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡Simpson, Maxwell, M.D., LL.D., F.R.S., F.C.S., Professor of Chemistry in Queen's College, Cork.
1876. ‡*Simpson, Robert. 14 Ibrox-terrace, Glasgow.*
Simpson, William. Bradmore House, Hammersmith, London, W.
1876. ‡*Sinclair, James. Titwood Bank, Pollockshields, near Glasgow.*
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1834. ‡Sinclair, Vetch, M.D. 48 Albany-street, Edinburgh.
1870. *Sinclair, W. P. 19 Devonshire-road, Prince's Park, Liverpool.
1864. *Sircar, Mahendra Lal, M.D. 51 Sankaritola, Calcutta. (Care of Messrs. S. Harraden & Co., 3 Hill's-place, Oxford-street, London, W.)
1865. ‡Sissons, William. 92 Park-street, Hull.
1879. ‡Skertchly, Sydney B. J., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1870. §Sladen, Walter Percy, F.G.S., F.L.S. Exley House, near Halifax.
1873. ‡Slater, Clayton. Barnoldswick, near Leeds.

Year of Election.

1870. ‡Slater, W. B. 42 Clifton Park-avenue, Belfast.
1842. *Slater, William. Park-lane, Higher Broughton, Manchester.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S., F.R.M.S. Clifton, Bristol.
1849. ‡Sloper, George Elgar. Devizes.
1849. ‡Sloper, Samuel W. Devizes.
1860. §§Sloper, S. Elgar. Winterton, near Hythe, Southampton.
1872. ‡Smale, The Hon. Sir John, Chief Justice of Hong Kong.
1867. ‡Small, David. Gray House, Dundee.
1881. §Smallshan, John. 81 Manchester-road, Southport.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1876. ‡Smeiton, James. Panmure Villa, Broughty Ferry, Dundee.
1876. ‡Smeiton, John G. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smeiton, Thomas A. 55 Cowgate, Dundee.
1876. §Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1857. ‡Smith, Aquilla, M.D., M.R.I.A. 121 Lower Baggot-street, Dublin.
1868. ‡*Smith, Augustus. Northwood House, Church-road, Upper Norwood, Surrey, S.E.*
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead Heath, London, N.W.
1874. *Smith, Benjamin Leigh. 64 Gower-street, London, W.C.
1873. ‡Smith, C. Sidney College, Cambridge.
1865. ‡SMITH, DAVID, F.R.A.S. 40 Bennett's-hill, Birmingham.
1865. ‡Smith, Frederick. The Priory, Dudley.
1866. *Smith, F. C. Bank, Nottingham.
1855. ‡Smith, George. Port Dundas, Glasgow.
1876. ‡Smith, George. Glasgow.
*SMITH, HENRY JOHN STEPHEN, M.A., LL.D., F.R.S., F.R.A.S., F.C.S., Savilian Professor of Geometry in the University of Oxford, and Keeper of the University Museum. The Museum, Oxford.
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, London, W.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1870. ‡*Smith, James. 146 Bedford-street South, Liverpool.*
1871. *Smith, John Alexander, M.D., F.R.S.E. 10 Palmerston-place, Edinburgh.
1876. *Smith, J. Guthrie. 173 St. Vincent-street, Glasgow.
1874. ‡Smith, John Haigh. Beech Hill, Halifax, Yorkshire.
Smith, John Peter George. Sweyney Cliff, near Coalport, Shropshire.
1871. ‡Smith, Professor J. William Robertson. Free Church College, Aberdeen.
*Smith, Philip, B.A. The Bays, Parkfields, Putney, S.W.
1860. *Smith, Protheroe, M.D. 42 Park-street, Grosvenor-square, London, W.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1847. §SMITH, ROBERT ANGUS, Ph.D., F.R.S., F.C.S. 22 Devonshire-street, Manchester.
*Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. ‡Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1873. ‡Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hessle, near Hull.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton, Bristol.

Year of
Election.

1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1878. ‡Smithson, Joseph S. Balnagowan, Rathmines, Co. Dublin.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1850. *Smyth, Charles Piazzi, F.R.S.E., F.R.A.S., Astronomer Royal for Scotland, Professor of Astronomy in the University of Edinburgh. 15 Royal-terrace, Edinburgh.
1874. ‡Smyth, Henry, C.E. Downpatrick, Ireland.
1870. ‡Smyth, Colonel H. A., R.A. Barrackpore, near Calcutta.
1878. §Smyth, Mrs. Isabella. Wigmore Lodge, Cullenswood-avenue, Dublin.
1857. *Smyth, John, jun., M.A., C.E., F.M.S. Lenaderg, Banbridge, Ireland.
1864. ‡Smyth, Warington W., M.A., F.R.S., F.G.S., F.R.G.S., Lecturer on Mining and Mineralogy at the Royal School of Mines, and Inspector of the Mineral Property of the Crown. 5 Inverness-terrace, Bayswater, London, W.
1854. ‡Smythe, Lieut.-General W. J., R.A., F.R.S. Athenæum Club, Pall Mall, London, S.W.
1878. §Snell, H. Saxon. 22 Southampton-buildings, London, W.C.
1879. §Sollas, W. J., M.A., F.R.S.E., F.G.S., Professor of Geology in University College, Bristol. 4 The Polygon, Clifton, Bristol.
*Solly, Edward, F.R.S., F.L.S., F.G.S., F.S.A. Park House, Sutton, Surrey.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *Sorby, H. Clifton, LL.D., F.R.S., F.G.S. Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Sheffield.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1856. ‡Southwood, Rev. T. A. Cheltenham College.
1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham.
1863. *Spark, H. King. Starforth House, Barnard Castle.
1879.§§Spence, David. Brookfield House, Freyinghall, Yorkshire.
1869. *Spence, J. Berger. Erlington House, Manchester.
1854. §Spence, Peter, F.C.S. Erlington House, Seymour-grove, Manchester.
1881. §Spencer, Herbert E. Lord Mayor's Walk, York.
1861. ‡Spencer, John Frederick. 28 Great George-street, London, S.W.
1861. *Spencer, Joseph. Springbank, Old Trafford, Manchester.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1875. ‡Spencer, W. H. Richmond Hill, Clifton, Bristol.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, London, N.
1864. §Spicer, William R. 19 New Bridge-street, Blackfriars, London, E.C.
1864. *Spiller, John, F.C.S. 2 St. Mary's-road, Canonbury, London, N.
1878. §Spottiswoode, George Andrew. 3 Cadogan-square, London, S.W.
1846. *Spottiswoode, William, M.A., D.C.L., LL.D., Pres. R.S., F.R.A.S., F.R.G.S. 41 Grosvenor-place, London, S.W.
1864. *Spottiswoode, W. Hugh. 41 Grosvenor-place, London, S.W.
1854. *Sprague, Thomas Bond. 29 Buckingham-terrace, Edinburgh.
1853. ‡Spratt, Joseph James. West Parade, Hull.
Square, Joseph Elliot, F.G.S. 24 Portland-place, Plymouth.
1877. ‡Square, William, F.R.C.S., F.R.G.S. 4 Portland-square, Plymouth.
*Squire, Lovell. The Observatory, Falmouth.
1879. ‡Stacye, Rev. John. Shrewsbury Hospital, Sheffield.
1858. *Stainton, Henry T., F.R.S., F.L.S., F.G.S. Mountsfield, Lewisham, S.E.

Year of Election.

1865. §STANFORD, EDWARD C. C. Glenwood, Dalmuir, N.B.
1837. Staniforth, Rev. Thomas. Storrs, Windermere.
1881. §Stanley, William Ford. Cumberlow, South Norwood, Surrey, S.E.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1866. ‡Starey, Thomas R. Daybrook House, Nottingham.
1876. §Starling, John Henry, F.C.S. The Avenue, Erith, Kent.
Staveley, T. K. Ripon, Yorkshire.
1873. *Stead, Charles. Saltaire, Bradford, Yorkshire.
1881. §Stead, John. Southport, Lancashire.
1881. §Stead, W. H. Southport, Lancashire.
1857. ‡Steale, William Edward, M.D. 15 Hatch-street, Dublin.
1870. §Stearn, C. H. 2 St. Paul's-villas, Rock Ferry, Liverpool.
1863. ‡Steele, Rev. Dr. 35 Sydney-buildings, Bath.
1873. §Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1861. †Steinthal, H. M. Hollywood, Fallowfield, near Manchester.
1872. ‡Stennett, Mrs. Eliza. 2 Clarendon-terrace, Brighton.
1879. *STEPHENSON, HENRY, J.P. Endcliffe Vale, Sheffield.
1881. §Stephenson, J. F. 3 Mount-parade, York.
1861. *Stern, S. J. Littlegrove, East Barnet, Herts.
1863. ‡Sterriker, John. Driffield, Yorkshire.
1876. ‡Steuart, Walter. City Bank, Pollockshaws, near Glasgow.
1870. *Stevens, Miss Anna Maria. Belmont, Devizes-road, Salisbury.
1861. *Stevens, Henry, F.S.A., F.R.G.S. 4 Trafalgar-square, London, W.C.
1880. *Stevens, J. Edward. 10 Cleveland-terrace, Swansea.
1868. ‡Stevenson, Henry, F.L.S. Newmarket-road, Norwich.
1878. ‡Stevenson, Rev. James, M.A. 21 Garville-avenue, Rathgar, Dublin.
1863. *STEVENSON, JAMES C., M.P., F.C.S. Westoe, South Shields.
1855. ‡STEWART, BALFOUR, M.A., LL.D., F.R.S., Professor of Natural Philosophy in Owens College, Manchester.
1864. ‡STEWART, CHARLES, M.A., F.L.S. St. Thomas's Hospital, London, S.E.
1875. *Stewart, James, B.A., M.R.C.P.Ed. Dunmurry, Sneyd Park, near Bristol.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1868. ‡*Stirling, Edward. 34 Queen's-gardens, Hyde Park, London, W.*
1876. ‡Stirling, William, M.D., D.Sc. The University, Aberdeen.
1867. *Stirrup, Mark, F.G.S. 14 Atkinson-street, Deansgate, Manchester.
1865. *Stock, Joseph S. The Grange, Ramsgate.
1864. ‡STODDART, WILLIAM WALTER, F.G.S., F.C.S. Grafton Lodge, Sneyd Park, Bristol.
1854. ‡Stoess, Le Chevalier Ch. de W. (Bavarian Consul). Liverpool.
*STOKES, GEORGE GABRIEL, M.A., D.C.L., LL.D., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1862. ‡STONE, EDWARD JAMES, M.A., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1874. ‡Stone, J. Harris, B.A., F.L.S., F.C.S. 11 Sheffield-gardens, Kensington, London, W.
1876. ‡Stone, Octavius C., F.R.G.S. Springfield, Nuneaton.
1859. ‡Stone, Dr. William H. 14 Dean's-yard, Westminster, S.W.
1857. ‡STONEY, BINDON B., C.E., F.R.S. M.R.I.A., Engineer of the Port of Dublin. 42 Wellington-road, Dublin.
1878. *Stoney, G. Gerald. 3 Palmerston Park, Dublin.
1861. *STONEY, GEORGE JOHNSTONE, M.A., F.R.S., M.R.I.A., Secretary to the Queen's University, Ireland. 3 Palmerston Park, Dublin.

Year of Election.

1876. §Stopes, Henry, F.G.S. Kenwyn, Cintra Park, Upper Norwood, S.E.
1854. Store, George. Prospect House, Fairfield, Liverpool.
1873. ‡Storr, William. The 'Times' Office, Printing-house-square, London, E.C.
1867. ‡*Storrar, John, M.D. Heathview, Hampstead, London, N.W.*
1859. §Story, Captain James. 17 Bryanston-square, London, W.
1874. §Stott, William. Greetland, near Halifax, Yorkshire.
1871. *STRACHEY, Lieut.-General RICHARD, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S. Stowey House, Clapham Common, London, S.W.
1881. §Strahan, Aubrey, M.A., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1876. ‡Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.
1881. §Strangways, C. Fox, F.G.S. Geological Museum, Jermyn-street, London, S.W.
*Strickland, Charles. Loughglyn House, Castlerea, Ireland.
1879. ‡Strickland, Sir Charles W., K.C.B. Hildenley-road, Malton.
Strickland, William. French Park, Roscommon, Ireland.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1867. ‡Stronner, D. 14 Princess-street, Dundee.
1876. *STRUTHERS, JOHN, M.D., Professor of Anatomy in the University of Aberdeen.
1878. ‡Strype, W. G., C.E. Wicklow.
1876. *Stuart, Charles Maddock. Sudbury Hill, Harrow.
1872. *Stuart, Rev. Edward A. 22 Bedford-street, Norwich.
1864. ‡Style, Sir Charles, Bart. 102 New Sydney-place, Bath.
1873.§§Style, Rev. George, M.A. Giggleswick School, Yorkshire.
1879. *Styring, Robert. 3 Hartshead, Sheffield.
1857. ‡SULLIVAN, WILLIAM K., Ph.D., M.R.I.A. Queen's College, Cork.
1873. ‡Sutcliffe, J. W. Sprink Bank, Bradford, Yorkshire.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne.
1862. *SUTHERLAND, GEORGE GRANVILLE WILLIAM, Duke of, K.G., F.R.S., F.R.G.S. Stafford House, London, S.W.
1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1881. §Sutton, William. Town Hall, Southport.
1881. §Swales, William. Ashville, Holgate-road, York.
1876. ‡Swan, David, jun. Braeside, Maryhill, Glasgow.
1881. §Swan, Joseph W. Mosley-street, Newcastle-on-Tyne.
1861. *Swan, Patrick Don S. Kirkcaldy, N.B.
1862. *SWAN, WILLIAM, LL.D., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews, N.B.
1862. *Swann, Rev. S. Kirke, F.R.A.S. Forest Hill Lodge, Warsop, Mansfield, Nottinghamshire.
1879. §Swanwick, Frederick. Whittington, Chesterfield.
Sweetman, Walter, M.A., M.R.I.A. 4 Mountjoy-square North, Dublin.
1870. *Swinburne, Sir John, Bart. Capheaton, Newcastle-on-Tyne.
1863. ‡Swindell, J. S. E. Summerhill, Kingswinford, Dudley.
1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1873. §Sykes, Benjamin Clifford, M.D. Cleckheaton.
1847. ‡Sykes, H. P. 47 Albion-street, Hyde Park, London, W.
1862. ‡Sykes, Thomas. Cleckheaton, near Leeds.
1847. ‡Sykes, Captain W. H. F. 47 Albion-street, Hyde Park, London, W.
SYLVESTER, JAMES JOSEPH, M.A., LL.D., F.R.S. Athenæum Club, London, S.W.

Year of
Election.

1870. ‡SYMES, RICHARD GLASCOTT, A.B., F.G.S. Geological Survey of Ireland, 14 Hume-street, Dublin.
1881. §Symington, Thomas. 13 Dundas-street, Edinburgh.
1856. *Symonds, Frederick, M.A., F.R.C.S. 35 Beaumont-street, Oxford.
1859. ‡Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi, London, W.C.
1860. ‡SYMONDS, Rev. W. S., M.A., F.G.S. Pendock Rectory, Worcestershire.
1859. §SYMONS, G. J., F.R.S., Sec.M.S. 62 Camden-square, London, N.W.
1855. *SYMONS, WILLIAM, F.C.S. 26 Joy-street, Barnstaple.
Synge, Francis. Glanmore, Ashford, Co. Wicklow.
1872. ‡Synge, Major-General Millington, R.E., F.S.A., F.R.G.S. United Service Club, Pall Mall, London, S.W.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.
1877. *TAIT, LAWSON, F.R.C.S. 7 Great Charles-street, Birmingham.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1867. ‡TAIT, P. M., F.R.G.S., F.S.S. Oriental Club, Hanover-square, London, W.
1874. §Talmage, C. G., F.R.A.S. Leyton Observatory, Essex, E.
1866. ‡Tarbotton, Marrott Ogle, M.I.C.E., F.G.S. Newstead-grove, Nottingham.
1878. ‡TARPEY, HUGH. Dublin.
1861. *Tarratt, Henry W. Mountfield, Grove Hill, Tunbridge Wells.
1856. ‡Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1857. *Tate, Alexander, C.E. Longwood, Whitehouse, Belfast.
1863. ‡Tate, John. Alnmouth, near Alnwick, Northumberland.
1870. ‡Tate, Norman A. 7 Nivell-chambers, Fazackerley-street, Liverpool.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1876. ‡Tatlock, Robert R. 26 Burnbank-gardens, Glasgow.
1879. ‡Tattershall, William Edward. 15 North Church-street, Sheffield.
1864. *TAWNEY, EDWARD B., F.G.S. Woodwardian Museum, Cambridge.
1878. *Taylor, A. Claude. Clinton-terrace, Derby-road, Nottingham.
1874. ‡Taylor, Alexander O'Driscoll. 3 Upper-crescent, Belfast.
1867. ‡Taylor, Rev. Andrew. Dundee.
1880. §Taylor, Edmund. Droitwich.
Taylor, Frederick. Laurel Cottage, Rainhill, near Prescot, Lancashire.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1881. *Taylor, H. A. 112 Cromwell-road, London, S.W.
1879. ‡Taylor, John. Broomhall-place, Sheffield.
1861. *Taylor, John. 6 Queen-street-place, Upper Thames-street, London, E.C.
1873. ‡TAYLOR, JOHN ELLOR, Ph.D., F.L.S., F.G.S. The Mount, Ipswich.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
*TAYLOR, RICHARD, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1878. ‡Taylor, Robert, J.P., LL.D. Corballis, Drogheda.
1881. §Taylor, Rev. S. B., M.A., Chaplain of Lower Assam, Gauhatti, Assam. (Care of Messrs. Grindlay & Co., 55 Parliament-street, London, S.W.)
1870. ‡Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.

Year of
Election.

*Taylor, William Edward. Hesketh Park, Southport.
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
1880. §§Tebb, Miss. 7 Albert-road, Regent's Park, London, N.W.
1869. ‡Teesdale, C. S. M. Whyke House, Chichester.
1876. ‡Temperley, Ernest. Queen's College, Cambridge.
1879. §Temple, Lieutenant George T., R.N. The Nash, near Worcester.
1880. §Temple, Sir Richard, Bart., G.C.S.I., F.R.G.S. Athenæum Club, London, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
1881. §Terry, Mr. Alderman. Mount-villas, York.
1866. ‡Thackeray, J. L. Arno Vale, Nottingham.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡THISELTON-DYER, W. T., M.A., B.Sc., F.R.S., F.L.S. 10 Gloucester-road, Kew.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1879. *Thomas, Arthur. Endcliffe House, Sheffield.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1875. *THOMAS, CHRISTOPHER JAMES. Drayton Lodge, Redland, Bristol.
Thomas, George. Brislington, Bristol.
1875. ‡Thomas, Herbert. 2 Great George-street, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1881. §THOMAS, J. BLOUNT. Southampton.
1869. ‡Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
1880. *Thomas, Joseph William, F.C.S. The Laboratory, West Wharf, Cardiff.
1881. §Thomas, Sydney G. 27 Tedworth-square, London, S.W.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1859. ‡Thompson, George, jun. Pidsmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, London, W.
Thompson, Henry Stafford. Fairfield, near York.
1861. *Thompson, Joseph. Riversdale, Wilmslow, Manchester.
1864. ‡THOMPSON, Rev. JOSEPH HESSELGRAVE, B.A. Cradley, near Brierley Hill.
1873. ‡Thompson, M. W. Guiseley, Yorkshire.
1876. *Thompson, Richard. Park-street, The Mount, York.
1874. ‡Thompson, Robert. Walton, Fortwilliam Park, Belfast.
1876. §THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.A.S., Professor of Physics in University College, Bristol.
1863. ‡Thompson, William. 11 North-terrace, Newcastle-on-Tyne.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1855. ‡THOMSON, ALLEN, M.D., LL.D., F.R.S. L. & E. 66 Palace Gardens-terrace, Kensington, London, W.
1850. ‡THOMSON, Sir CHARLES WYVILLE, LL.D., F.R.S. L. & E., F.G.S., Regius Professor of Natural History in the University of Edinburgh. 20 Palmerston-place, Edinburgh.
Thomson, Guy. Oxford.
1850. *THOMSON, Professor JAMES, M.A., LL.D., C.E., F.R.S. L. & E. Oakfield House, University Avenue, Glasgow.
1868. §THOMSON, JAMES, F.G.S. 3 Abbotsford-place, Glasgow.
*Thomson, James Gibson. 14 York-place, Edinburgh.
1876. ‡Thomson, James R. Dalmuir House, Dalmuir, Glasgow.
1874. ‡Thomson, John. Harbour Office, Belfast.
1871. *THOMSON, JOHN MILLAR, F.C.S. King's College, London, W.C.
1871. ‡Thomson, Robert, LL.B. 12 Rutland-square, Edinburgh.

Year of Election.

1847. *Thomson, Sir William, M.A., LL.D., D.C.L., F.R.S. L. & E., Professor of Natural Philosophy in the University of Glasgow, The University, Glasgow.
1877. *Thomson, Lady. The University, Glasgow.
1874. §Thomson, William, F.R.S.E., F.C.S. Royal Institution, Manchester.
1876. ‡*Thomson, William.* 6 *Mansfield-place, Edinburgh.*
1871. ‡*Thomson, William Burnes, F.R.S.E.* 1 *Ramsay-gardens, Edinburgh.*
1880. §Thomson, William J. St. Helen's, Lancashire.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1852. ‡Thornburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
*Thornton, Samuel, J.P. Oakfield, Moseley, near Birmingham.
1867. ‡Thornton, Thomas. Dundee.
1845. ‡Thorp, Dr. Disney. Lyppiatt Lodge, Suffolk Lawn, Cheltenham.
1881. §Thorp, Fielden. Blossom-street, York.
1871. ‡Thorp, Henry. Briarleigh, Sale, near Manchester.
1881. *Thorp, Josiah. New Mills, near Huddersfield.
1864. *Thorp, William, B.Sc., F.C.S. 39 Sandringham-road, Kingsland, London, E.
1871. ‡Thorpe, T. E., Ph.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in Yorkshire College, Leeds.
1868. ‡Thuillier, Lieut.-General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S. 32 Cambridge-terrace, Hyde Park, London, W.
1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.
1873. *Tiddeman, R. H., M.A., F.G.S. 28 Jermyn-street, London, S.W.
1874. ‡Tilden, William A., D.Sc., F.R.S., F.C.S. Clifton College, Bristol.
1873. ‡Tilghman, B. C. Philadelphia, United States.
1865. ‡Timmins, Samuel, J.P., F.S.A. Elvetham-road, Edgbaston, Birmingham.
Tinker, Ebenezer. Mealhill, near Huddersfield.
*Tinne, John A., F.R.G.S. Briarley, Aigburth, Liverpool.
1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, London, S.E.
1861. *Todhunter, Isaac, M.A., F.R.S., Principal Mathematical Lecturer at St. John's College, Cambridge. Brookside, Cambridge.
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1856. ‡Tomes, Robert Fisher. Welford, Stratford-on-Avon.
1864. *Tomlinson, Charles, F.R.S., F.C.S. 3 Ridgmount-terrace, Highgate, London, N.
1863. ‡*Tone, John F. Jesmond-villas, Newcastle-on-Tyne.*
1865. §Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1865. §Tonks, William Henry. The Rookery, Sutton Coldfield.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.
1861. *Topham, John, M.I.C.E. High Elms, 265 Mare-street, Hackney, London, E.
1872. *Topley, William, F.G.S., A.I.C.E. Geological Survey Office, Jermyn-street, London, S.W.
1875. §Torr, Charles Hawley. Harrowby House, Park-row, Nottingham.
1863. §Torrens, Colonel Sir R. R., K.C.M.G. 12 Chester-place, Hyde Park, London, W.
1859. ‡Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus, N.B.
Towgood, Edward. St. Neot's, Huntingdonshire.
1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875. ‡Townsend, Charles. Avenue House, Cotham Park, Bristol.

Year of Election.

1857. *TOWNSEND, Rev. RICHARD, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1877. ‡Tozer, Henry. Ashburton.
1876. *Trail, Professor J. W. H., M.A., M.D., F.L.S. University of Aberdeen, Old Aberdeen.
1870. ‡TRAILL, WILLIAM A., M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1875. ‡Trapnell, Caleb. Severnleigh, Stoke Bishop.
1868. ‡TRAQUAIR, RAMSAY H., M.D., F.R.S., Professor of Zoology. Museum of Science and Art, Edinburgh.
1835. Travers, Robert, M.B. Williamstown, Blackrock, Co. Dublin.
1865. ‡Travers, William, F.R.C.S. 1 Bath-place, Kensington, London, W.
Tregelles, Nathaniel. Liskeard, Cornwall.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1869. ‡Trehane, John, jun. Bedford-circus, Exeter.
1870. ‡Trench, Dr. Municipal Offices, Dale-street, Liverpool.
Trench, F. A. Newlands House, Clondalkin, Ireland.
1871. ‡TRIBE, ALFRED, F.C.S. 14 Denbigh-road, Bayswater, London, W.
1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.
1877. ‡TRIMEN, HENRY, M.B., F.L.S. British Museum, London, W.C.
1871. ‡TRIMEN, ROWLAND, F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1860. §TRISTRAM, Rev. HENRY BAKER, M.A., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1869. ‡Tucker, Charles. Marlands, Exeter.
1847. *Tuckett, Francis Fox. 10 Baldwin-street, Bristol.
Tuke, James H. Bank, Hitchen.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1867. ‡Tulloch, The Very Rev. Principal, D.D. St. Andrews, Fifeshire.
1881. §Tully, G. T. 10 West Cliff-terrace, Preston.
1854. ‡TURNBULL, JAMES, M.D. 86 Rodney-street, Liverpool.
1855. §Turnbull, John. 37 West George-street, Glasgow.
1856. ‡Turnbull, Rev. J. C. 8 Bays-hill-villas, Cheltenham.
1871. ‡Turnbull, William, F.R.S.E. 14 Lansdowne-crescent, Edinburgh.
1873. *Turner, George. Horton Grange, Bradford, Yorkshire.
Turner, Thomas, M.D. 31 Curzon-street, Mayfair, London, W.
1875. ‡Turner, Thomas, F.S.S. Ashley House, Kingsdown, Bristol.
1863. *TURNER, WILLIAM, M.B., F.R.S. L. & E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1842. Twamley, Charles, F.G.S. Ryton-on-Dunsmore, Coventry.
1847. ‡TWISS, Sir TRAVERS, Q.C., D.C.L., F.R.S., F.R.G.S. 3 Paper-buildings, Temple, London, E.C.
1865. ‡TYLOR, EDWARD BURNETT, D.C.L., F.R.S. Linden Wellington, Somerset.
1858. *TYNDALL, JOHN, D.C.L., LL.D., Ph.D., F.R.S., F.G.S., Professor of Natural Philosophy in the Royal Institution. Royal Institution, Albemarle-street, London, W.
1861. *Tysoe, John. 28 Heald-road, Bowdon, near Manchester.

1876. *UNWIN, W. C., A.I.C.E., Professor of Hydraulic Engineering. Cooper's Hill, Middlesex.
1872. ‡Upward, Alfred. 11 Great Queen-street, Westminster, London, S.W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1859. †Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.

Year of Election.

1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1880. §USSHER, W. A. E., F.G.S. 28 Jermyn-street, London, S.W.

*Vance, Rev. Robert. 24 Blackhall-street, Dublin.
1863. ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M. Tunisienne, Geneva.
1854. ‡Varley, Cromwell F., F.R.S. Cromwell House, Bexley Heath, Kent.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, London, N.
1865. *VARLEY, S. ALFRED. Hatfield, Herts.
1870. ‡Varley, Mrs. S. A. Hatfield, Herts.
1869. ‡Varwell, P. Alphington-street, Exeter.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1849. *Vaux, Frederick. Central Telegraph Office, Adelaide, South Australia.
1873. *VERNEY, Captain EDMUND H., R.N., F.R.G.S. Rhianva, Bangor, North Wales.
Verney, Sir Harry, Bart., M.P. Lower Claydon, Buckinghamshire.
1866. ‡Vernon, Rev. E. H. Harcourt. Cotgrave Rectory, near Nottingham.
Vernon, George John, Lord. 32 Curzon-street, London, W.; and Sudbury Hall, Derbyshire.
1879.§§Veth, D. D. Leiden, Holland.
1864. *VICARY, WILLIAM, F.G.S. The Priory, Colleton-crescent, Exeter.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1875. ‡Vines, David, F.R.A.S. Observatory House, Somerset-street, Kingsdown, Bristol.
1856. ‡VIVIAN, EDWARD, M.A. Woodfield, Torquay.
*VIVIAN, H. HUSSEY, M.P., F.G.S. Park Wern, Swansea; and 27 Belgrave-square, London, S.W.
1856. §VOELCKER, J. CH. AUGUSTUS, Ph.D., F.R.S., F.C.S., Professor of Chemistry to the Royal Agricultural Society of England. 39 Argyll-road, Kensington, London, W.
1875. ‡*Volckman, Mrs. E. G.* 43 *Victoria-road, Kensington, London, W.*
1875. ‡*Volckman, William.* 43 *Victoria-road, Kensington, London, W.*
‡Vose, Dr. James. Gambier-terrace, Liverpool.

1860. §Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1859. ‡*Waddington, John. New Dock Works, Leeds.*
1879. *Wake, Bernard. Abbeyfield, Sheffield.
1870. §WAKE, CHARLES STANILAND. 2 Westbourne-avenue, Hull.
1873. ‡Wales, James. 4 Mount Royd, Manningham, Bradford, Yorkshire.
1869. *Walford, Cornelius. 86 Belsize Park-gardens, London, N.W.
1849. §WALKER, CHARLES V., F.R.S., F.R.A.S. Fernside, Reigate Hill, Reigate.
Walker, Frederick John. The Priory, Bathwick, Bath.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1855. ‡Walker, John. 1 Exchange-court, Glasgow.
1866. *WALKER, John Francis, M.A., F.C.P.S., F.C.S., F.G.S., F.L.S. 16 Gillygate, York.
1881. §Walker, John Sydenham. 83 Bootham, York.
1867. *Walker, Peter G. 2 Airlie-place, Dundee.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
Walker, William. 47 Northumberland-street, Edinburgh.
1881. *Walker, William. 14 Bootham-terrace, York.
1863. ‡WALLACE, ALFRED RUSSEL, F.R.G.S., F.L.S. Nutwood Cottage, Frith Hill, Godalming.

Year of Election.

1859. ‡WALLACE, WILLIAM, Ph.D., F.C.S. Chemical Laboratory, 138 Bath-street, Glasgow.
1857. ‡Waller, Edward. Lisenderry, Aughnacloy, Ireland.
1862. ‡Wallich, George Charles, M.D., F.R.G.S., F.L.S. 162 Holland-road, London, W.
1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., M.P., F.R.S. Ealing, Middlesex, W
Walsh, John (Prussian Consul). Dundrum Castle, Co. Dublin.
1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.
1881. §Walton, Thomas. Oliver's Mount School, Scarborough.
Walton, Thomas Todd. Mortimer House, Clifton, Bristol.
1863. ‡Wanklyn, James Alfred. 7 Westminster-chambers, London, S.W.
1872. ‡Warburton, Benjamin. Leicester.
1874. §Ward, F. D. Fernleigh, Botanic-road, Belfast.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡Ward, H. Marshall. Christ's College, Cambridge.
1874. §Ward, John, F.G.S., F.R.G.S. Lenox Vale, Belfast.
1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1880. *Ward, J. Westney. 41 Head-street, Colchester.
1863. ‡Ward, Robert. Dean-street, Newcastle-on-Tyne.
*Ward, William Sykes, F.C.S. 12 Bank-street, and Denison Hall, Leeds.
1867. ‡Warden, Alexander J. Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1865. ‡Waring, Edward John, M.D., F.L.S. 49 Clifton-gardens, Maida Vale, London, W.
1878. §WARINGTON, ROBERT, F.C.S. Harpenden, St. Albans, Herts.
1872. *Warner, Thomas. 47 Sussex-square, Brighton.
1856. ‡*Warner, Thomas H. Lee. Tiberton Court, Hereford.*
1875. ‡Warren, Algernon. Naseby House, Pembroke-road, Clifton, Bristol.
1865. *Warren, Edward P. 13 Old-square, Birmingham.
Warwick, William Atkinson. Wyddrington House, Cheltenham.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
1876. ‡Waterhouse, A. Willenhall House, Barnet, Herts.
1875. *Waterhouse, Major J. 1 Wood-street, Calcutta. (Care of Messrs. Trübner & Co., Ludgate-hill, London, E.C.)
1854. ‡Waterhouse, Nicholas. 5 Rake-lane, Liverpool.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1875.§§Waters, Arthur W., F.G.S., F.L.S. Woodbrook, Alderley Edge, near Manchester.
1875. ‡Watherston, Alexander Law, M.A., F.R.A.S. Bowdon, Cheshire.
1881. §Watherston, E. J. 12 Pall Mall East, London, S.W.
1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1855. ‡Watson, Ebenezer. 1 Woodside-terrace, Glasgow.
1867. ‡Watson, Frederick Edwin. Thickthorne House, Cringleford, Norwich.
*WATSON, HENRY HOUGH, F.C.S. 227 The Folds, Bolton-le-Moors.
1873. *Watson, Sir James. Milton-Lockhart, Carluke, N.B.
1859. ‡WATSON, JOHN FORBES, M.A., M.D., F.L.S. India Museum, London, S.W.
1863. ‡Watson, Joseph. Bensham-grove, near Gateshead-on-Tyne.
1863. ‡Watson, R. S. 101 Pilgrim-street, Newcastle-on-Tyne.
1867. ‡Watson, Thomas Donald. 41 Cross-street, Finsbury, London, E.C.
1879. *WATSON, WILLIAM HENRY, F.C.S. Braystones, near Whitehaven, Cumberland.
1869. ‡Watt, Robert B. E., C.E., F.R.G.S. Ashley-avenue, Belfast.
1861. ‡Watts, Sir James. Abney Hall, Cheadle, near Manchester.

Year of Election.

1875. *WATTS, JOHN, B.A., D.Sc. 57 Baker-street, Portman-square, London, W.
1846.§§Watts, John King, F.R.G.S. Market-place, St. Ives, Hunts.
1870. §Watts, William, F.G.S. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
Waud, Major E. Manston Hall, near Leeds.
Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.
1859. ‡Waugh, Edwin. Sager-street, Manchester.
1859. *WAVENEY, The Right Hon. Lord, F.R.S. 7 Audley-square, London, W.
*WAY, J. THOMAS, F.C.S. 9 Russell-road, Kensington, London, S.W.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
*WEBB, Rev. THOMAS WILLIAM, M.A., F.R.A.S. Hardwick Vicarage, Hay, South Wales.
1866. *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1859. ‡Webster, John. 42 King-street, Aberdeen.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.
1854. ‡Weightman, William Henry. Farn Lea, Seaforth, Liverpool.
1865. ‡Welch, Christopher, M.A. University Club, Pall Mall East, London, S.W.
1881. §Welcombe, Henry S. Station Hotel, York.
1867. §WELDON, WALTER, F.R.S.E. Rede Hall, Burstow, near Crawley, Surrey.
1876. §Weldon, W. F. R. St. John's College, Cambridge.
1879. §Wells, Charles A. Etna Iron Works, Lewes.
1881. §Wells, Rev. Edward, B.A. Flamstead Vicarage, Dunstable.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
1881. *Wenlock, The Right Hon. Lord. Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Whitehaven, Cumberland.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, London, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1870. ‡West, Captain E. W. Bombay.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1853. ‡West, Stephen. Hessle Grange, near Hull.
1870. §Westgarth, William. 10 Bolton-gardens, South Kensington, London, W.
1842. Westhead, Edward. Chorlton-on-Medlock, near Manchester.
1857. *Westley, William. 24 Regent-street, London, S.W.
1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.
1875. *Weston, Joseph D. Dorset House, Clifton Down, Bristol.
1864. ‡WESTROPP, W. H. S., M.R.I.A. Lisdoonvarna, Co. Clare.
1860. ‡WESTWOOD, JOHN O., M.A., F.L.S., Professor of Zoology in the University of Oxford. Oxford.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N.W.
1847. ‡Wheeler, Edmund, F.R.A.S. 48 Tollington-road, Holloway, London, N.
1878. *Wheeler, W. H., C.E. Churchyard, Boston, Lincolnshire.

Year of Election.

1879. *Whidborne, George Ferris, M.A., F.G.S. Charante, Torquay.
1873. ‡Whipple, George Matthew, B.Sc., F.R.A.S. Kew Observatory, Richmond, Surrey.
1874. ‡Whitaker, Henry, M.D. 33 High-street, Belfast.
1859. *WHITAKER, WILLIAM, B.A., F.G.S. Geological Survey Office, 28 Jermyn-street, London, S.W.
1876. ‡White, Angus. Easdale, Argyleshire.
1864. ‡*White, Edmund. Victoria Villa, Batheaston, Bath.*
1837. WHITE, JAMES, F.G.S. 8 Thurloe-square, South Kensington, London, S.W.
1876. *White, James. Overtoun, Dumbarton.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
White, John. 80 Wilson-street, Glasgow.
1859. ‡WHITE, JOHN FORBES. 16 Bon Accord-square, Aberdeen.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1869. ‡White, Laban. Blanford, Dorset.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 365 Euston-road, London, N.W.
1861. ‡Whitehead, James, M.D. 87 Mosley-street, Manchester.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. *Whitehead, Peter Ormerod, C.E. Drood House, Old Trafford, Manchester.
Whitehouse, William. 10 Queen's-street, Rhyl.
1871. ‡Whitelaw, Alexander. 1 Oakley-terrace, Glasgow.
1881. §Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1866. ‡Whitfield, Samuel. Eversfield, Eastnor-grove, Leamington.
1874. ‡*Whitford, William. 5 Claremont-street, Belfast.*
1852. ‡Whitla, Valentine. Beneden, Belfast.
Whitley, Rev. Charles Thomas, M.A., F.R.A.S. Bedlington, Morpeth.
1870. §Whittem, James Sibley. Walgrave, near Coventry.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. 94 Baggot-street, Dublin.
1874. *Whitwell, Mark. Redland House, Bristol.
*WHITWORTH, Sir JOSEPH, Bart., LL.D., D.C.L., F.R.S. Stancliffe, Matlock, Derbyshire.
1870. ‡WHITWORTH, Rev. W. ALLEN, M.A. 185 Islington, Liverpool.
1865. ‡Wiggin, Henry. Metchley Grange, Harborne, Birmingham.
1881. §Wigglesworth, James. Wakefield.
1881. *Wigglesworth, Robert. Minster-yard, York.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1881. §WILBERFORCE, W. W. Fishergate, York.
1855. ‡Wilkie, John. Westburn, Helensburgh, N.B.
1857. ‡Wilkinson, George. Temple Hill, Killiney, Co. Dublin.
1879. §Wilkinson, Joseph, F.R.G.S. York.
1859. §WILKINSON, ROBERT. Lincoln Lodge, Totteridge, Hertfordshire.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1869. §Wilks, George Augustus Frederick, M.D. Stanbury, Torquay.
*Willert, Alderman Paul Ferdinand. Town Hall, Manchester
1859. ‡Willet, John, C.E. 35 Albyn-place, Aberdeen.
1872. ‡WILLETT, HENRY, F.G.S. Arnold House, Brighton.
WILLIAMS, CHARLES JAMES B., M.D., F.R.S. 47 Upper Brook-street, Grosvenor-square, London, W.
1861. *Williams, Charles Theodore, M.A., M.B. 47 Upper Brook-street, Grosvenor-square, London, W.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 1 Gorse Lane, Swansea.
1875. *Williams, Herbert A., M.A. 91 Pembroke-road, Clifton, Bristol.

Year of
Election.

1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1870. §Williams, John, F.C.S. 14 Buckingham-street, London, W.C.
1875. *Williams, M. B. North Hill, Swansea.
1879. ‡Williams, Matthew W., F.C.S. 18 Kempsford-gardens, Earl's Court, London, S.W.
Williams, Robert, M.A. Bridehead, Dorset.
1869. ‡Williams, Rev. Stephen. Stonyhurst College, Whalley, Blackburn.
1877. *Williams, W. Carleton, F.C.S. Owens College, Manchester.
1865. ‡*Williams, W. M. Belmont-road, Twickenham, near London.*
1850. *Williamson, Alexander William, Ph.D., LL.D., For. Sec. R.S., F.C.S., Corresponding Member of the French Academy, Professor of Chemistry, and of Practical Chemistry, University College, London. (General Treasurer.) University College, London, W.C.
1857. ‡Williamson, Benjamin, M.A., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
1876. ‡Williamson, Stephen. 19 James-street, Liverpool.
Williamson, William C., F.R.S., Professor of Natural History in Owens College, Manchester. 4 Egerton-road, Fallowfield, Manchester.
1865. *Willmott, Henry. Hatherley Lawn, Cheltenham.
1859. *Wills, Alfred, Q.C. 12 King's Bench-walk, Inner Temple, London, E.C.
1865. ‡*Wills, Arthur W. Edgbaston, Birmingham.*
Wills, W. R. Edgbaston, Birmingham.
1878. ‡Wilson, Alexander S., M.A., B.Sc. 124 Bothwell-street, Glasgow.
1859. ‡Wilson, Alexander Stephen, C.E. North Kinmundy, Summerhill, by Aberdeen.
1876 ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1874. ‡Wilson, Major C. W., C.B., R.E., F.R.S., F.R.G.S., Director of the Topographical and Statistical Department of the War Office. 5 Lansdowne-terrace, Rodwell, Weymouth.
1850. ‡Wilson, Dr. Daniel. Toronto, Upper Canada.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 73 Newman-street, Oxford-street, London, W.
1861. ‡*Wilson, George Daniel.* 24 *Ardwick-green, Manchester.*
1875. §Wilson, George Fergusson, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1879. §§Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1855. ‡Wilson, Hugh. 75 Glasford-street, Glasgow.
1857. ‡Wilson, James Moncrieff. Queen Insurance Company, Liverpool.
1865. ‡Wilson, James M., M.A. The College, Clifton, Bristol.
1858. *Wilson, John. Seacroft Hall, near Leeds.
Wilson, John, F.G.S., F.R.S.E., Professor of Agriculture in the University of Edinburgh. The University, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1861. ‡*Wilson, Thomas Bright.* 24 *Ardwick-green, Manchester.*
1867. ‡Wilson, Rev. William. Free St. Paul's, Dundee.
1871. *Wilson, William E. Daramona House, Rathowen, Ireland.
1870. ‡*Wilson, William Henry.* 31 *Grove-park, Liverpool.*

Year of Election.

1861. *WILTSHIRE, Rev. THOMAS, M.A., F.G.S., F.L.S., F.R.A.S. 25 Granville-park, Lewisham, London, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1868. ‡Winter, C. J. W. 22 Bethel-street, Norwich.
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1881. *Wood, Alfred John. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Bridge of Earn, N.B.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.
*Wood, George B., M.D. 1117 Arch-street, Philadelphia, United States.
1870. *Wood, George S. 20 Lord-street, Liverpool.
1875. *Wood, George William Rayner. Singleton, Manchester.
1856. *WOOD, Rev. H. H., M.A., F.G.S. Holwell Rectory, Sherborne, Dorset.
1878. §Wood, H. Trueman, B.A. Society of Arts, John-street, Adelphi, London, W.C.
1881. §Wood, John, B.A., F.R.A.S. Wharfedale Cottage, Boston Spa, Yorkshire.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1871. ‡Wood, Provost T. Barleyfield, Portobello, Edinburgh.
1850. ‡Wood, Rev. Walter. Elie, Fife.
Wood, William. Edge-lane, Liverpool.
1865. *Wood, William, M.D. 99 Harley-street, London, W.
1861. ‡Wood, William Rayner. Singleton Lodge, near Manchester.
1872. §Wood, William Robert. Carlisle House, Brighton.
*Wood, Rev. William Spicer, M.A., D.D. Higham, Rochester.
1863. *WOODALL, Major JOHN WOODALL, M.A., F.G.S. St. Nicholas House, Scarborough.
1870. ‡Woodburn, Thomas. Rock Ferry, Liverpool.
1850. *Woodd, Charles H. L., F.G.S. Roslyn House, Hampstead, London, N.W.
1865. ‡Woodhill, J. C. Pakenham House, Charlotte-road, Edgbaston, Birmingham.
1871. †Woodiwis, James. 51 Back George-street, Manchester.
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
1869. ‡Woodman, William Robert, M.D. Ford House, Exeter.
*WOODS, EDWARD, C.E. 3 Great George-street, Westminster, London, S.W.
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, London, E.C.
*WOODWARD, C. J., B.Sc. 76 Francis-road, Edgbaston, Birmingham.
1866. ‡WOODWARD, HENRY, F.R.S., F.G.S. British Museum, London, W.C.
1870. ‡Woodward, Horace B., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1881. §Wooler, W. A. Sadberge Hall, Darlington.
1877. ‡Woollcombe, Robert W. 14 St. Jean d'Acre-terrace, Plymouth.
1856. ‡Woolley, Thomas Smith, jun. South Collingham, Newark.
1872. ‡Woolmer, Shirley. 6 Park-crescent, Brighton.
Worcester, The Right Rev. Henry Philpott, D.D., Lord Bishop of. Worcester.
1874. ‡Workman, Charles. Ceara, Windsor, Belfast.
1878. §§Wormell, Richard, M.A., D.Sc. 165 Loughborough-road, London, S.W.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.

Year of Election.

1855. *Worthington, Rev. Alfred William, B.A. Stourbridge. Worcestershire.

Worthington, Archibald. Whitchurch, Salop.

Worthington, James. Sale Hall, Ashton-on-Mersey.

Worthington, William. Brockhurst Hall, Northwich, Cheshire.

1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, London, N.W.

1879. §Wrentmore, Francis. 34 Holland Villas-road, Kensington, London, S.W.

1871. §Wright, C. R. A., D.Sc., F.R.S., F.C.S., Lecturer on Chemistry in St. Mary's Hospital Medical School, Paddington, London, W.

1861. *Wright, E. Abbot. Castle Park, Frodsham, Cheshire.

1857. ‡Wright, E. Perceval, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany, and Director of the Museum, Dublin University 5 Trinity College, Dublin.

1866. ‡*Wright, G. H. Heaton Hall, near Derby.*

1876. ‡Wright, James. 114 John-street, Glasgow.

1874. ‡Wright, Joseph. Cliftonville, Belfast.

1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.

*Wright, Robert Francis. Hinton Blewett, Temple-Cloud, near Bristol.

1855. ‡Wright, Thomas, M.D., F.R.S. L. & E., F.G.S. St. Margaret's-terrace, Cheltenham.

Wright, T. G., M.D. Milnes House, Wakefield.

1876. ‡Wright, William. 101 Glassford-street, Glasgow.

1871. ‡Wrightson, Thomas. Norton Hall, Stockton-on-Tees.

1867. ‡Wünsch, Edward Alfred. 146 West George-street, Glasgow.

Wyld, James, F.R.G.S. Charing Cross, London, W.C.

1863. *Wyley, Andrew. 21 Barker-street, Handsworth, Birmingham.

1867. ‡Wylie, Andrew. Prinlaws, Fifeshire.

1871. ‡Wynn, Mrs. Williams. Cefn, St. Asaph.

1862. ‡Wynne, Arthur Beevor, F.G.S., of the Geological Survey of India. Bombay.

1875. ‡Yabbicom, Thomas Henry, C.E. 37 White Ladies-road, Clifton, Bristol.

*Yarborough, George Cook. Camp's Mount, Doncaster.

1865. ‡Yates, Edwin. Stonebury, Edgbaston, Birmingham.

Yates, James. Carr House, Rotherham, Yorkshire.

1867. ‡Yeaman, James. Dundee.

1879. ‡Yeomans, John. Upperthorpe, Sheffield.

1877. §Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.

1879. *York, His Grace the Archbishop of, D.D., F.R.S. The Palace, Bishopsthorpe, Yorkshire.

1870. ‡Young, James, F.R.S. L. & E., F.C.S. Kelly, Wemyss Bay, by Greenock.

1876. *Young, James, jun., F.C.S. Kelly, Wemyss Bay, by Greenock.

1876. ‡Young, John, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.

1868. ‡Youngs, John. Richmond Hill, Norwich.

1876. ‡Yuille, Andrew. 7 Sardinia-terrace, Hillhead, Glasgow.

1871. ‡Yule, Colonel Henry, C.B. 3 Penywern-road, South Kensington, London, S.W.

CORRESPONDING MEMBERS.

Year of
Election.

1871. HIS IMPERIAL MAJESTY THE EMPEROR OF THE BRAZILS.
1881. Professor G. F. Barker. University of Pennsylvania, Philadelphia.
1870. Professor Van Beneden, LL.D. Louvain, Belgium.
1872. Ch. Bergeron, C.E. 26 Rue des Penthièvre, Paris.
1861. Dr. Bergsma, Director of the Magnetic Survey of the Indian Archipelago. Utrecht, Holland.
1880. Professor Ludwig Boltzmann. Halbärtgasse, 1, Gräz, Austria.
1864. Dr. H. D. Buys-Ballot, Superintendent of the Royal Meteorological Institute of the Netherlands. Utrecht Holland.
1861. Dr. Carus. Leipzig.
1864. M. Des Cloizeaux. Paris.
1855. Dr. Ferdinand Cohn. Breslau, Prussia.
1871. Professor Dr. Colding. Copenhagen.
1881. Professor Josiah P. Cooke. Harvard University, United States.
1873. Signor Guido Cora. 17 Via Providenza, Turin.
1880. Professor Cornu. L'École Polytechnique, Paris.
1870. *J. M. Crafts, M.D.*
1876. Professor Luigi Cremona. The University, Rome.
1872. *Professor M. Croullebois.* 18 *Rue Sorbonne, Paris.*
1866. Dr. Geheimrath von Dechen. Bonn.
1862. Wilhelm Delffs, Professor of Chemistry in the University of Heidelberg.
1872. Professor G. Devalque. Liége, Belgium.
1870. Dr. Anton Dohrn. Naples.
Professor Dumas. L'Institut, Paris.
1881. Captain J. B. Eads, C.E. St. Louis, United States.
1876. Professor Alberto Eccher. Florence.
1848. Professor Esmark. Christiania.
1861. Professor A. Favre. Geneva.
1874. Dr. W. Feddersen. Leipzig.
1872. W. de Fonvielle. Rue des Abbesses, Paris.
1856. Professor E. Frémy. L'Institut, Paris.
1842. M. Frisiani.
1881. C. M. Gariel, C.E., Secretary of the French Association for the Advancement of Science, Paris.
1866. Dr. Gaudry, Pres. Geol. Soc. of France. Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1870. Governor Gilpin. Colorado, United States.
1876. Dr. Benjamin A. Gould, Director of the Argentine National Observatory, Cordoba.
1852. Professor Asa Gray. Harvard University, United States.
1866. Professor Edward Grube, Ph.D. Breslau.
1871. Dr. Paul Güssfeldt, of the University of Bonn. 33 Meckenheimerstrasse, Bonn, Prussia.
1862. Dr. D. Bierens de Haan, Member of the Royal Academy of Sciences, Amsterdam. Leiden, Holland.
1876. Professor Ernst Haeckel. Jena.

Year of Election.

1881. Dr. Edwin H. Hall. Baltimore, United States.
1872. Professor James Hall. Albany, State of New York.
1881. M. Halphen. 21 Rue Ste. Anne, Paris.
1864. M. Hébert, Professor of Geology in the Sorbonne, Paris.
1877. Professor H. L. F. Helmholtz. Berlin.
1868. A. Heynsius. Leiden.
1872. J. E. Hilgard, Assist.-Supt. U.S. Coast Survey. Washington.
1861. Dr. Hochstetter. Vienna.
1881. Dr. A. A. W. Hubrecht. Leiden.
1876. Professor von Quintus Icilius. Hanover.
1867. Dr. Janssen, LL.D. 21 Rue Labat (18° Arrondissement), Paris.
1876. Dr. W. J. Janssen. The University, Leiden.
1862. Charles Jessen, Med. et Phil. Dr., Professor of Botany in the University of Greifswald, and Lecturer on Natural History and Librarian at the Royal Agricultural Academy, Eldena, Prussia.
1881. Professor W. Woolsey Johnson. Annapolis, United States.
1876. Dr. Giuseppe Jung. 26 Via Monforte, Milan.
1877. M. Akin Kàroly. 5 Babenbergerstrasse, Vienna.
1862. Aug. Kekulé, Professor of Chemistry. Bonn.
1873. Dr. Felix Klein. Munich, Bavaria.
1874. Dr. Knoblauch. Halle, Germany.
1856. Professor A. Kölliker. Wurzburg, Bavaria.
Laurent-Guillaume De Koninck, M.D., Professor of Chemistry and Palæontology in the University of Liége, Belgium.
1877. Dr. Hugo Kronecker, Professor of Physiology. 35 Dorotheenstrasse, Berlin.
1876. Professor von Lasaulx. Breslau.
1872. M. Georges Lemoine. 76 Rue d'Assas, Paris.
1877. Dr. M. Lindeman, Hon. Sec. of the Bremen Geographical Society, Bremen.
1846. Baron de Selys-Longchamps. Liége, Belgium.
1871. Professor Jacob Lüroth. Technische Hochschule, Munich.
1871. Dr. Lütken. Copenhagen.
1869. Professor C. S. Lyman. Yale College, New Haven, United States.
1867. Professor Mannheim. Rue de la Pompe, 11, Passy, Paris.
1881. Professor O. C. Marsh. Yale College, Newhaven, United States.
1867. Professor Ch. Martins, Director of the Jardin des Plantes. Montpellier, France.
1862. Professor P. Merian. Bâle, Switzerland.
1848. Professor J. Milne-Edwards. Paris.
1855. M. l'Abbé Moigno. Paris.
1877. Professor V. L. Moissenet. L'École des Mines, Paris.
1864. Dr. Arnold Moritz. St. Petersburg, Russia.
1856. Edouard Morren, Professeur de Botanique à l'Université de Liége, Belgium.
1875. Dr. T. Nachtigal. Berlin.
1866. Chevalier C. Negri, President of the Italian Geographical Society, Turin, Italy.
1864. Herr Neumayer. Deutsche Seewarte, Hamburg.
1869. Professor H. A. Newton. Yale College, New Haven, United States.
1874. M. A. Niaudet. 6 Rue du Seine, Paris.
1848. Professor Nilsson. Lund, Sweden.
1856. M. E. Peligot, Memb. de l'Institut, Paris.
1857. Gustav Plarr. 22 Hadlow-road, Tunbridge, Kent.
1870. Professor Felix Plateau. Rue du Casino, 15, Gand, Belgium.
1868. Professor L. Radlkofer, Professor of Botany in the University of Munich.

Year of Election.

1872. Professor Victor von Richter. St. Petersburg.

1873. Baron von Richthofen, President of the Berlin Geographical Society, 71 Steglitzer-strasse, Berlin.

M. de la Rive. Geneva.

1866. F. Röemer, Ph.D., Professor of Geology and Palæontology in the University of Breslau. Breslau, Prussia.

1850. Professor W. B. Rogers. Boston, United States.

1881. Professor Henry A. Rowland. Baltimore, United States.

1857. Baron Herman de Schlagintweit-Sakünlünski. Jaegersberg Castle, near Forchheim, Bavaria.

1857. Professor Robert Schlagintweit. Giessen.

1874. Dr. G. Schweinfurth. Cairo.

1872. Professor Carl Semper. Wurzburg, Bavaria.

1873. Dr. A. Shafarik. Prague.

1861. M. Werner Siemens. Berlin.

1849. Dr. Siljeström. Stockholm.

1876. Professor R. D. Silva. École Centrale, Paris.

1873. Professor J. Lawrence Smith. Louisville, United States.

1864. Adolph Steen, Professor of Mathematics. Copenhagen.

1866. Professor Steenstrup. Copenhagen.

1881. Dr. Cyparissos Stephanos. 28 Rue de l'Arbaléte, Paris.

1881. Professor Stürm. Münster, Westphalia.

1845. Dr. Svanberg. Upsala.

1871. Dr. Joseph Szabo. Pesth, Hungary.

1870. Professor Tchebichef, Membre de l'Académie de St. Pétersbourg.

1852. M. Pierre de Tchihatchef, Corresponding Member of the Institute of France. 1 Piazza degli Zuaai, Florence.

1864. Dr. Otto Torell, Professor of Geology in the University of Lund, Sweden.

Arminius Vámbéry, Professor of Oriental Languages in the University of Pesth, Hungary.

1842. Professor Wartmann. Geneva.

1881. Professor H. M. Whitney. Beloit College, Wisconsin, United States.

1874. Professor Wiedemann. Leipzig.

1876. Professor Adolph Wüllner. Aix-la-Chapelle.

1872. Professor A. Wurtz. Paris.

1875. Dr. E. L. Youmans. New York.

LIST OF SOCIETIES AND PUBLIC INSTITUTIONS

TO WHICH A COPY OF THE REPORT IS PRESENTED.

GREAT BRITAIN AND IRELAND

Admiralty, Library of the.
Anthropological Institute.
Arts, Society of.
Asiatic Society (Royal).
Astronomical Society (Royal).
Belfast, Queen's College.
Birmingham, Midland Institute.
Bristol Philosophical Institution.
Cambridge Philosophical Society.
Chemical Society.
Civil Engineers, Institute of.
Cornwall, Royal Geological Society of.
Dublin, Royal College of Surgeons in Ireland.
——, Royal Geological Society of Ireland.
——, Royal Irish Academy.
——, Royal Society of.
East India Library.
Edinburgh, Royal Society of.
——, Royal Medical Society of.
——, Scottish Society of Arts.
Exeter, Albert Memorial Museum.
Geographical Society (Royal).
Geological Society.
Geology, Museum of Practical.
Glasgow Philosophical Society.
——, Institution of Engineers and Shipbuilders in Scotland.
Greenwich, Royal Observatory.
Kew Observatory.
Leeds, Mechanics' Institute.
Leeds, Philosophical and Literary Society of.
Linnean Society.
Liverpool, Free Public Library and Museum.
——, Royal Institution.
London Institution.
Manchester Literary and Philosophical Society.
——, Mechanics' Institute.
Mechanical Engineers, Institute of.
Meteorological Office.
Newcastle-upon-Tyne Literary and Philosophical Society.
Nottingham, The Free Library.
Oxford, Ashmolean Society.
——, Radcliffe Observatory.
Plymouth Institution.
Physicians, Royal College of.
Royal Engineers' Institute, Chatham.
Royal Institution.
Royal Society.
Salford, Royal Museum and Library.
Statistical Society.
Stonyhurst College Observatory.
Surgeons, Royal College of.
United Service Institution.
University College.
War Office, Library of the.
Wales (South), Royal Institution of.
Yorkshire Philosophical Society.
Zoological Society.

EUROPE.

Alten, Lapland. Literary and Philosophical Society.
Berlin ....Der Kaiserlichen Akademie der Wissenschaften.
—— ....Royal Academy of Sciences.
Breslau ....Silesian Patriotic Society.
Bonn ....University Library.
Brussels ....Royal Academy of Sciences.
Charkow ....University Library.
Coimbra ....Meteorological Observatory.
Copenhagen ...Royal Society of Sciences.
Dorpat, Russia...University Library.
Frankfort ......Natural History Society.
Geneva ....Natural History Society.
Göttingen ......University Library.
Harlem ....Société Hollandaise des Sciences.
Heidelberg ......University Library.

Helsingfors ......University Library.
Kasan, Russia ...University Library.
Kiel ....Royal Observatory.
Kiev.................University Library.
Lausanne..........The Academy.
Leyden ....University Library.
Liége ....University Library.
Lisbon ....Academia Real des Sciences.
Milan ....The Institute.
Modena ....Royal Academy.
Moscow ....Society of Naturalists.
——................University Library.
Munich ....University Library.
Naples ....Royal Academy of Sciences.
Nicolaieff..........University Library.
Paris ....Association Française pour l'Avancement des Sciences.
—— ....Geographical Society.
—— ....Geological Society.
Paris ....Royal Academy of Sciences.
—— ....School of Mines.
Pultova ....Imperial Observatory.
Rome ....Accademia dei Lyncei.
—— ....Collegio Romano.
—— ....Italian Geographical Society.
—— ....Italian Society of Sciences.
St. Petersburg . University Library.
—— ....Imperial Observatory.
Stockholm ......Royal Academy.
Turin ....Royal Academy of Sciences.
Utrecht ....University Library.
Vienna............The Imperial Library.
—— ....Central Anstalt für Meteorologie und Erdmagnetismus.
Zurich............General Swiss Society.

ASIA.

Agra ....The College.
Bombay ....Elphinstone Institution.
—— ....Grant Medical College.
Calcutta ....Asiatic Society.
Calcutta ....Hindoo College.
—— ....Hoogly College.
—— ....Medical College.
Madras............The Observatory.
—— ....University Library.

AFRICA.

Cape of Good Hope . . . The Observatory.

AMERICA.

Albany ....The Institute.
Boston ....American Academy of Arts and Sciences.
Cambridge ......Harvard University Library.
New York ......Lyceum of Natural History.
Philadelphia ...American Medical Association.
Philadelphia ...American Philosophical Society.
—— ....Franklin Institute.
Toronto ....The Observatory.
Washington ...Smithsonian Institution.
—— ....United States Geological Survey of the Territories.

AUSTRALIA.

Adelaide . . . . The Colonial Government.
Victoria . . . . The Colonial Government.

Spottiswoode & Co., Printers, New-street Square, London.

50, ALBEMARLE STREET,
February, 1882.

MR. MURRAY'S LIST.

COMPLETION OF THE SPEAKER'S COMMENTARY.

The New Testament.

Complete in 4 Vols. Medium 8vo. £4 14*s.*

VOL. I.—THE SYNOPTIC GOSPELS. 18*s.*

GENERAL INTRODUCTION ...... ARCHBISHOP OF YORK.
ST. MATTHEW .... Dean MANSEL and EDITOR.
ST. MARK .... The EDITOR.
ST. LUKE .... BISHOP OF ST. DAVID'S, and EDITOR.

VOL. II.—ST. JOHN & THE ACTS. 20*s.*

ST. JOHN .... Canon WESTCOTT.
ACTS........................ BISHOP OF CHESTER.

VOL. III.—EPISTLES OF ST. PAUL. 28*s.*

ROMANS .... Canon GIFFORD.
CORINTHIANS .... { Canon EVANS. J. WAITE, M.A.
GALATIANS .... DEAN OF CHESTER.
PHILIPPIANS, EPHESIANS, COLOSSIANS, THESSALONIANS, PHILEMON............ { Prebendary MEYRICK. BISHOP OF DERRY. DEAN OF RAPHOE.
PASTORAL EPISTLES............ BISHOP OF LONDON, and Prof. WACE.

VOL. IV.—HEBREWS TO REVELATION. 28*s.*

HEBREWS .... Canon KAY.
ST. JAMES .... DEAN OF ROCHESTER.
ST. JOHN........................ BISHOP OF DERRY.
ST. PETER, ST. JUDE............... Professor J. R. LUMBY.
REVELATION........................ Archdeacon LEE.

EXTRACT FROM THE PREFACE.

Eighteen years have now passed since this Commentary on the Holy Scriptures was undertaken. Its publication was commenced ten years ago, and the concluding volume is now presented to the public. Its conception was due to the late Lord Ossington, then Speaker of the House of Commons, and to that circumstance it owes its familiar title of "The Speaker's Commentary"—a title, however, which derives a further justification from the warm interest he maintained in the progress of the work and the constant encouragement it received from him. * * * * * *

The Editor cannot but express his deep thankfulness that a work involving so many difficulties, and liable to so many unforeseen disturbances, should thus have been brought to its conclusion without any substantial deviation either from the principles or the form adopted and explained at its commencement. * * * * * *

As stated on the title page, it was from the outset a primary purpose of the Commentary to furnish in the notes corrected translations of all passages in which the old version required revision. These emendations of the authorized version, when deemed certain, have throughout the work been printed in a distinctive type, darker than the rest of the note; and the reader is thus enabled to see at a glance every correction in rendering which modern scholarship has made really necessary. The work thus done presents substantially the advantages of a revised version—a circumstance on which it is desirable to insist in view of the scheme for providing such a version, which about eight years afterwards was set on foot, and has since been partially executed.

The Outlook.

A CHARGE DELIVERED AT HIS PRIMARY VISITATION IN NOVEMBER, 1881,

BY THE LORD BISHOP OF ROCHESTER.

With a Map. 8vo. *2s.*

CONTINUATION OF

Elwin's Edition of the Works of Pope.

VOLUME III. of the POETRY.

CONTAINING THE SATIRES, MORAL ESSAYS, &c., WITH INTRODUCTION AND NOTES.

EDITED BY W. J. COURTHOPE, M.A.

With Facsimiles. 8vo. *10s. 6d.*

The Edition will be completed in 10 Vols.

ALREADY PUBLISHED:

VOLS. I. & II.—POETRY. VOLS. VI., VII. & VIII.—PROSE WORKS.

"To take up the Edition at the point where Mr. Elwin had broken off demanded a great amount of tact and judgment . . . . This delicate operation of passing over from injustice to just appreciation has been executed by the new editor with consummate tact and skill. He comes to each point of the Pope case neither as an advocate nor as a prosecutor, but in a thoroughly judicial spirit."—*Mr. Mark Pattison in the "Academy."*

Life and Correspondence of Dr. Arnold,

FORMERLY HEAD MASTER OF RUGBY, AND PROFESSOR OF MODERN HISTORY AT OXFORD.

BY ARTHUR PENRHYN STANLEY, D.D.

Late Dean of Westminster.

Twelfth Edition, with the Author's final Corrections, and an Unpublished Poem by REV. JOHN KEBLE.

With Portrait. 2 Vols. Crown 8vo. *12s.*

The Odyssey of Homer,

BOOKS XIII.—XXIV.

RENDERED INTO ENGLISH VERSE.

BY GENERAL G. A. SCHOMBERG, C.B.

8vo. *12s.*

Already published, BOOKS I.—XII. 8vo. *12s.*

Life, Works, and Times of Titian.

WITH SOME ACCOUNT OF HIS FAMILY, CHIEFLY FROM NEW AND UNPUBLISHED RECORDS.

BY J. A. CROWE AND G. B. CAVALCASELLE.

Second and Cheaper Edition. With Portrait and Illustrations. 2 Vols. 8vo. *21s.*

"Messrs. Crowe and Cavalcaselle's labours appear in two handsome volumes, full of the richest and most reliable material ably handled and disposed. The 'Life and Times of Titian' are here, and we read the volumes and put them among the most necessary of our works of reference in the history of Art."—*Fraser's Magazine.*

Handbook of Travel Talk.

IN ENGLISH, GERMAN, FRENCH, AND ITALIAN.

PREPARED EXPRESSLY FOR ENGLISH TRAVELLERS ABROAD, AND FOREIGNERS VISITING ENGLAND.

Sixteenth Edition, thoroughly Revised. 16mo. 3*s.* 6*d.*

The "Handbook of Travel Talk" is not a reprint of old Manuals of Conversation "drawn up towards the end of the last century," but a modern traveller's phrase book, compiled expressly to meet the wants of the day. Ample space is given to Railway Travelling (Taking Tickets—In the Train—The Station, &c.), Post Office, Telegraph, Luggage Office, and to the multitude of technical words and phrases which the progress of modern civilisation has developed. During the Fifteen Editions which it has passed through, it has undergone constant improvement: the consequence is, that it contains many words of modern invention not to be found in dictionaries.

THE

Voyage of the "Fox" in the Arctic Seas

IN SEARCH OF SIR JOHN FRANKLIN AND HIS COMPANIONS.

BY SIR LEOPOLD McCLINTOCK, R.N.

Fifth Edition, containing a SUPPLEMENTARY CHAPTER *on the recent Searching Expeditions of Capt.* C. F. HALL *and Lieut.* F. SCHWATKA, *U.S.A.*

With Maps and Thirty Illustrations. Post 8vo. 7*s.* 6*d.*

Life and Works of Michel Angelo,

SCULPTOR, PAINTER, AND ARCHITECT.

INCLUDING INEDITED DOCUMENTS FROM THE BUONARROTI ARCHIVES.

BY CHARLES HEATH WILSON.

Second and Cheaper Edition. With an Index and Engravings. 8vo. 15*s.*

English Studies;

OR, ESSAYS IN ENGLISH HISTORY AND LITERATURE.

BY J. S. BREWER, M.A.,

OF THE RECORD OFFICE, PREACHER AT THE ROLLS, PROFESSOR OF MODERN HISTORY, KING'S COLL., LONDON.

EDITED WITH MEMOIR BY HENRY WACE, M.A.,

Preacher of Lincoln's Inn, Professor of Ecclesiastical History in King's College, London.

8vo. 14*s*.

CONTENTS:

New Sources of English History.
Green's History of the English People.
Hatfield House.
Royal Supremacy.
The Stuarts.
Shakspeare.
English History.
Ancient London.
Erasmus.
Study of History.

Life of Samuel Wilberforce,

LORD BISHOP OF OXFORD, AND WINCHESTER,

WITH SELECTIONS FROM HIS DIARIES AND CORRESPONDENCE,

1805—1860.

BY CANON ASHWELL, & REGINALD G. WILBERFORCE.

5*th Thousand.* With Portraits and Woodcuts. Vols. I. & II. 8vo. 15*s*. each.

India in 1880.

BY SIR RICHARD TEMPLE, BART., G.C.S.I., C.I.E., D.C.L.

Late Governor of Bombay, Lieut.-Governor of Bengal, and Finance Minister of India.

Second Edition. With 2 Maps. 8vo. 16*s*.

The Eastern Question.

BEING A

SELECTION FROM WRITINGS DURING THE LAST YEARS OF HIS LIFE.

BY LORD STRATFORD DE REDCLIFFE, K.G., G.C.B.

WITH PREFACE BY DEAN STANLEY.

With Map. 8vo. 9*s*.

The Cat.

AN INTRODUCTION TO THE STUDY OF BACK-BONED ANIMALS, ESPECIALLY MAMMALS.

BY ST. GEORGE MIVART, F.R.S.,

Author of "Lessons from Nature," &c., &c. Vice-President of the Linnean Society and of the Zoological Society.

With 200 Illustrations. Medium 8vo. 30*s.*

"The present volume is expressly intended to be an introduction to the natural history of the whole group of *back-boned* animals. . . . but the subject has been so treated as to fit it also to serve as an introduction to Zoology generally, and even to Biology . . . . The sciences subordinate to Biology are also enumerated and defined."

One of the principal features of this work is that, while giving a detailed account of one animal, it serves to explain the principles and leading facts of all the different sciences with which the student of Natural History has to deal.

"We have great pleasure in warmly recommending the work to all who are interested in zoology or natural history."—*Lancet.*

The Manifold Witness for Christ.

AN ATTEMPT TO EXHIBIT THE COMBINED FORCE OF VARIOUS EVIDENCES OF CHRISTIANITY, DIRECT AND INDIRECT.

THE BOYLE LECTURES FOR 1877–78.

BY ALFRED BARRY, D.D., D.C.L.

Principal of King's College, London; Canon of Westminster; and Honorary Chaplain to the Queen.

8vo. 12*s.*

Life and Letters of Lord Campbell.

LORD CHIEF JUSTICE, AND AFTERWARDS LORD CHANCELLOR OF ENGLAND.

BASED ON HIS AUTOBIOGRAPHY, JOURNALS, AND CORRESPONDENCE.

EDITED BY THE HON. MRS. HARDCASTLE.

Second Edition. With Portrait. 2 Vols. 8vo. 30*s.*

Mrs. Grote: a Sketch.

BY LADY EASTLAKE.

Second Edition. Post 8vo. 6*s.*

THE PUBLIC LIFE OF RIGHT HON.

John Charles Herries,

DURING THE REIGNS OF GEORGE III., GEORGE IV., WILLIAM IV., AND QUEEN VICTORIA.

FOUNDED ON HIS LETTERS AND OTHER UNPUBLISHED DOCUMENTS.

BY HIS SON EDWARD HERRIES, C.B.

2 vols. 8vo. 24*s.*

BY DR. HENRY SCHLIEMANN.

Ilios.

A Complete History of the City and Country of the Trojans.

Including an Autobiography of the Author.

With 2,000 Illustrations. Imperial 8vo. 50*s.*

Mycenæ and Tiryns.

A Narrative of Researches and Discoveries.

With a Preface by the Rt. Hon. W. E. Gladstone.

With 500 Illustrations. Medium 8vo. 50*s.*

BY MISS ISABELLA BIRD.

Unbeaten Tracks in Japan;

Travels of a Lady in the Interior of Japan.

Including Visits to the Aborigines of Yezo and the Shrines of Nikko and Isé.

Fourth Edition. With Illustrations. 2 Vols. Crown 8vo. 24*s.*

A Lady's Life in the Rocky Mountains.

Fourth Edition. With Illustrations. Post 8vo. 7*s.* 6*d.*

Six Months in the Sandwich Islands.

Fourth Edition. With Illustrations. Post 8vo. 7*s.* 6*d.*

BY LADY ANNE BLUNT.

A Pilgrimage through the Desert to Nejd, the Cradle of the Arab Race.

And a Visit to the Court of the Arab Emir, and Our Persian Campaign.

Second Edition. With Map and Illustrations. 2 Vols. Crown 8vo. 24*s.*

Travels among the Bedouin Tribes of the Euphrates.

With some Account of the Arabs and their Horses.

With Map and Illustrations. 2 Vols. Crown 8vo. 24*s.*

Personal Life of David Livingstone.

FOUNDED ON HIS JOURNALS AND CORRESPONDENCE HITHERTO UNPUBLISHED.

BY WM. GARDEN BLAIKIE, D.D., LL.D.

Second Edition. WITH A CHAPTER ON THE SOUTH AFRICAN BOERS AND SLAVERY.

With Portrait and Map. 8vo. 15*s.*

Afghanistan and South Africa.

LETTERS TO THE RIGHT HON. W. E. GLADSTONE, M.P., REGARDING PORTIONS OF HIS "MIDLOTHIAN SPEECHES."

BY THE RIGHT HON. SIR BARTLE FRERE, BART., G.C.B., G.C.S.I., F.R.S., &c.

WITH A LETTER TO THE LATE SIR JOHN KAYE, AND OTHER PAPERS.

Fourth Edition. (76 pp.) 8vo. 1*s.*

Handbook to Political Questions of the Day.

With the Arguments on either side.

By SYDNEY C. BUXTON. *Third Edition.* Containing "THE THREE F's."—LOCAL SELF-GOVERNMENT.—LONDON MUNICIPAL REFORM.—BUSINESS OF THE HOUSE OF COMMONS.—DISFRANCHISEMENT, ETC. 8vo. 6*s.*

A History of Ancient Geography among the Greeks and Romans.

From the Earliest Ages till the fall of the Roman Empire.

By E. H. BUNBURY, F.R.G.S. With 20 Maps. 2 Vols. 8vo. 42*s.*

Nile Gleanings;

The Ethnology, History, and Art of Ancient Egypt, as Revealed by the Paintings and Bas-reliefs. With explorations of Nubia and its great Rock Temples to the Second Cataract.

By VILLIERS STUART, of Dromana, M.P. With 58 Coloured Lithographs and Plates from Impressions from the Monuments. Royal 8vo. 31*s.* 6*d.*

History of British Commerce,

And of the Progress of the Nation, from 1763 to 1878.

By LEONE LEVI, F.S.A., Barrister-at-Law, Professor of the Principles and Practice of Commerce and Commercial Law, King's College, London. *Revised and Enlarged Edition.* With Diagrams. 8vo. 18*s.*

The Power of Movement in Plants.

By **CHAS. DARWIN, F.R.S.**, assisted by **FRANCIS DARWIN.** *2nd Thousand.* With Woodcuts. Crown 8vo. 15*s.*

The Light Cavalry Brigade in the Crimea:

Extracts from Letters and Journals during the Crimean War.

By Gen. **LORD GEO. PAGET.** Map. Crown 8vo. 10*s.* 6*d.*

Old English Plate.

Ecclesiastical, Decorative, and Domestic.

With Improved Tables of the Date-Letters.

By **WILFRED J. CRIPPS, M.A., F.S.A.** *Second and Revised Edition.* 70 Illustrations. Medium 8vo. 16*s.*

Life of Dr. Erasmus Darwin.

With a Study of his Scientific Work.

By **CHARLES DARWIN, F.R.S.**, and **ERNEST KRAUSE.** Portrait and Woodcuts. 8vo. 7*s.* 6*d.*

British Burma.

Sketches of the Natives, their Manners and Customs.

By **CAPT. FORBES**, Late Deputy-Commissioner. Crown 8vo. 10*s.* 6*d.*

Gleanings of Past Years, 1843—78.

By The Right Hon. **W. E. GLADSTONE, M.P.** 7 vols. Small 8vo. 2*s.* 6*d.* each.

Household Surgery; or Hints for Emergencies.

By **JOHN F. SOUTH,** formerly one of the Surgeons to St. Thomas's Hospital. *Fourth Edition.* With new Preface and Additions. Woodcuts. Fcap. 8vo. 3*s.* 6*d.*

Old French Plate.

Furnishing Tables of the Paris Date-letters and Facsimiles of other Marks.

By **WILFRED J. CRIPPS M.A., F.S.A.** With Illustrations. 8vo. 8*s.* 6*d.*

The Country of the Moors.

A Journey from Tripoli in Barbary, through Tunis, to the Holy City of Kairwân.

By **EDWARD RAE,** Author of "The Land of the North Wind." With Maps, Plans, and 6 Etchings. Crown 8vo. 12*s.*

Life of Dr. John Wilson.

Missionary, Philanthropist, and Scholar in Bombay.

By **GEORGE SMITH, LL.D.** *Popular Edition.* With Portrait and Illustrations. Crown 8vo. 9*s.*

The Student's Commentary on the Old Testament.

ABRIDGED FROM THE SPEAKER'S COMMENTARY, AND

EDITED BY REV. JOHN M. FULLER, M.A.
Vicar of Bexley, Kent, and formerly Fellow of St. John's College, Cambridge.

4 Vols. Crown 8vo. *7s. 6d.* each.

VOL. I.—GENESIS TO DEUTERONOMY.
,, II.—JOSHUA TO ESTHER.
VOL. III.—JOB TO SONG OF SOLOMON.
,, IV.—ISAIAH TO MALACHI.

A CYCLOPÆDIA OF EARLY CHURCH HISTORIES.

A Dictionary of Christian Antiquities.

The History and Institutions of the Christian Church, from the Time of the Apostles to the Age of Charlemagne.

By VARIOUS WRITERS. Edited by WM. SMITH, D.C.L., and ARCHDEACON CHEETHAM, D.D. With Illustrations. 2 Vols. Medium 8vo. £3 13*s.* 6*d.*

A Dictionary of Christian Biography.

Literature, Sects, and Doctrines. From the time of the Apostles to the Age of Charlemagne.

By VARIOUS WRITERS. Edited by WM. SMITH, D.C.L., and HENRY WACE, M.A. [*To be completed in* 4 *vols.*] Vols. I. and II. Medium 8vo. 31*s.* 6*d.* each.

The Manners & Customs of the Ancient Egyptians.

By Sir J. GARDNER WILKINSON. A New Edition, revised by SAMUEL BIRCH, LL.D. With 500 Illustrations, Coloured Plates, &c. 3 Vols. Medium 8vo. 84*s.*

Mediæval Architecture.

Its Rise and Development. Lectures Delivered at the Royal Academy.

By the late Sir G. GILBERT SCOTT, R.A. With 450 Illustrations. 2 Vols. Medium 8vo. 42*s.*

50, ALBEMARLE STREET,
February, 1882.

MR. MURRAY'S FORTHCOMING WORKS.

SERMONS ON PUBLIC OCCASIONS, PREACHED IN WESTMINSTER ABBEY.

By ARTHUR PENRHYN STANLEY,
LATE DEAN OF WESTMINSTER.

CONTENTS:

A REASONABLE, HOLY, AND LIVING SACRIFICE.
DEDICATION OF WESTMINSTER ABBEY.
CORONATION OF WILLIAM THE CONQUEROR AND ITS CONSEQUENCES.
THE ALTAR OF WESTMINSTER ABBEY.
RELIGIOUS ASPECT OF SCULPTURE.
A THREEFOLD CALL.
NATIONAL THANKSGIVING.
ENGLAND AND INDIA.
RETURN OF THE TRAVELLER.
LORD PALMERSTON.
CHARLES DICKENS.
SCIENCE AND RELIGION.
RELIGIOUS ASPECT OF HISTORY.
MISSION OF THE TRAVELLER.
CHARLES KINGSLEY.
RELIGIOUS ASPECT OF GEOLOGY.
RELIGIOUS USE OF WISDOM.
RELIGIOUS ASPECT OF GOTHIC ARCHITECTURE.
THE PRINCESS ALICE.
AN INDIAN STATESMAN.
CARLYLE.
DAYS OF OLD.
EARL OF BEACONSFIELD.
CHRISTIAN FRATERNITY.
DIVERSITY IN UNITY.
CLOSE OF THE MISSION SERVICES, 1879.
DISTRESS OF PARIS.
CHRISTIAN RULE OF SPEECH.
CRUSADE OF CHARITY.
THE GREEK MASSACRE.

8vo.

THE WHITE SEA PENINSULA.

A JOURNEY TO THE WHITE SEA, AND THE KOLA PENINSULA.

By EDWARD RAE, F.R.G.S.
Author of "The Land of the North Wind," "The Country of the Moors," &c.

With Map, 14 *Etchings, and* 13 *Woodcuts. Crown 8vo.* 15*s.* [*Ready.*

ALBERT DÜRER: HIS LIFE AND WORKS.

By MORIZ THAUSING,
Keeper of the Albertina Collection at Vienna.

EDITED BY F. A. EATON, SECRETARY TO THE ROYAL ACADEMY.

Portraits and other Illustrations. 2 *Vols. Medium 8vo.* 42*s.*

"We are glad to learn that an English translation of Herr Thausing's valuable Life of Albert Dürer is in the press, and will be published by the end of the year. It will be welcomed by all English lovers of art, and the more so as the German original is not very easy reading."—*Quarterly Review.*

SHOULD THE REVISED NEW TESTAMENT BE AUTHORIZED.

By **SIR EDMUND BECKETT, Bart., Q.C.**
Chancellor and Vicar-General of York.

Post 8*vo.* 6*s.* [*Ready.*

AN ARGUMENT FOR THE DIVINITY OF JESUS CHRIST.

Translated from 'LE CHRISTIANISME ET LES TEMPS PRESENTS,' of the ABBÉ EM. BOUGAUD.

By **C. L. CURRIE.**

Post 8*vo.* 6*s.* [*Ready.*

SPEECHES AND ADDRESSES,

POLITICAL AND LITERARY.

DELIVERED IN THE HOUSE OF LORDS, IN CANADA, AND ELSEWHERE.

By the **EARL OF DUFFERIN,**
Late Governor-General of Canada, Ambassador at the Court of the Sultan.

8*vo.*

THE GOSPEL AND ITS WITNESSES.

THE PRINCIPAL FACTS IN THE LIFE OF OUR LORD, AND THE AUTHORITY OF THE EVANGELICAL NARRATIVES.

CONSIDERED IN SIX LECTURES DELIVERED AT ST. JAMES'S, WESTMINSTER.

By **HENRY WACE, M.A.**
Preacher of Lincoln's Inn, &c.

Crown 8*vo.*

MEN AND EVENTS OF MY TIME IN INDIA.

By SIR RICHARD TEMPLE, Bart.,
Author of "India in 1880.'

8vo.

CONTENTS:—Close of Lord Hardinge's Administration—Thomason's Government of the North-Western Provinces—Duumvirate in the Panjab of the Lawrence Brothers —John Lawrence, Administrator-in-Chief of the Panjab—Dalhousie the great Pro-Consul —The War of the Mutinies—Canning the Just—James Wilson the Economist—Samuel Laing the Financier—The Central Provinces—Sir Bartle Frere and Western India—The Indian Foreign Secretaryship—John Lawrence as Viceroy—The Finance Ministership—Lord Mayo's Indian Career—Lord Northbrook and the Bengal Famine—The Government of Bengal—Affairs of Southern India—The Bombay Presidency.

THIRD VOLUME OF THE

DICTIONARY OF CHRISTIAN BIOGRAPHY,

INCLUDING LITERATURE, SECTS, AND DOCTRINES, FROM THE TIME OF THE APOSTLES TO THE AGE OF CHARLEMAGNE.

Edited by DR. WM. SMITH and PROFESSOR WACE.

To be completed in 4 *Vols. Medium* 8*vo.*

THE BEATITUDES.

AND SERMONS ADDRESSED TO CHILDREN,

IN WESTMINSTER ABBEY.

By ARTHUR PENRHYN STANLEY, D.D.,
Late Dean of Westminster.

CONTENTS

THE BEATITUDES.
THE CHILD JESUS.
LITTLE CHILDREN, LOVE ONE ANOTHER.
THE USE OF CHILDREN.
THE 'GOLIATH' BOYS.
THE CHILDREN'S PSALMS.
SICK CHILDREN.
ST. CHRISTOPHER.
THE CHILDREN'S CREED.
TALITHA CUMI.

Post 8*vo.*

"DELIVER US FROM EVIL."

A SECOND LETTER TO THE BISHOP OF LONDON

IN REPLY TO THE

THREE LETTERS OF THE BISHOP OF DURHAM.

By F. C. COOK, M.A.,
Canon of Exeter, and Editor of "The Speaker's Commentary on the Bible."

8vo. 3*s.* [*Ready.*

RECREATIONS AND STUDIES OF A COUNTRY CLERGYMAN OF THE LAST CENTURY.

BEING SELECTIONS FROM THE CORRESPONDENCE OF THE

Rev. THOMAS TWINING, M.A.,

SOMETIME FELLOW OF SIDNEY SUSSEX COLLEGE, AND RECTOR OF ST. MARY-AT-THE-WALLS, COLCHESTER.

TRANSLATOR OF "ARISTOTLE ON POETRY."

8vo.

COMPLETION OF THE

STUDENT'S COMMENTARY ON THE OLD TESTAMENT.

Vol. IV.—ISAIAH TO MALACHI.

ABRIDGED FROM "THE SPEAKER'S COMMENTARY," AND

Edited by J. M. FULLER, M.A.,
Vicar of Bexley, and formerly Fellow of St. John's College, Cambridge.

Crown 8vo. 7*s.* 6*d.*

THIRD AND CONCLUDING VOLUME OF THE

LIFE OF BISHOP WILBERFORCE.

FROM THE YEAR 1860 TO HIS DEATH.

By his Son, REGINALD G. WILBERFORCE.

With Portrait. 8vo.

GREECE:

PICTORIAL, DESCRIPTIVE, AND HISTORICAL.

By CHRISTOPHER WORDSWORTH, D.D.,
Bishop of Lincoln.

WITH AN INTRODUCTION ON THE CHARACTERISTICS OF GREEK ART, BY GEORGE SCHARF, F.S.A.

A Revised Edition, Edited by H. F. TOZER, M.A.,
Tutor of Exeter College, Oxford.

With Illustrations of Scenery, Architecture, Costume, and Fine Arts of the Country.

Royal 8vo.

A DICTIONARY OF HYMNOLOGY.

SETTING FORTH THE ORIGIN AND HISTORY OF THE HYMNS IN COMMON USE, A DESCRIPTION OF THE MOST POPULAR HYMNALS, AND BIOGRAPHICAL NOTICES OF THEIR AUTHORS AND TRANSLATORS.

By JOHN JULIAN, F.R.S.L.,
Vicar of Wincobank, Sheffield.

1. THE HISTORY OF EVERY HYMN IN GENERAL USE, EMBRACING ORIGINALS AND TRANSLATIONS.
2. NOTICES OF AUTHORS, TRANSLATORS, AND COMPILERS OF HYMNS.
3. ENQUIRIES INTO ANONYMOUS AUTHORS OF HYMNS.
4. ORIGINS OF HYMNS IN GREEK, LATIN, AND GERMAN—ON SERVICE BOOKS, BREVIARIES, EARLY HYMN BOOKS, &C.; HYMNS IN FOREIGN LANGUAGES, FRENCH, DANISH, AND GERMAN, &C., FROM WHICH TRANSLATIONS HAVE BEEN MADE INTO ENGLISH.
5. THE SOURCES OF ENGLISH HYMNOLOGY.

8vo.

THE MODERN DUCANGE.

A NEW MEDIÆVAL LATIN-ENGLISH DICTIONARY.

OCCUPYING THE GROUND OF DUCANGE, BUT EDITED IN ACCORDANCE WITH THE MODERN SCIENCE OF PHILOLOGY.

By E. A. DAYMAN, B.D.,
Prebendary of Sarum, formerly Fellow and Tutor of Exeter College, Oxford;

And J. H. HESSELS.

Small 4to.

THE GOSPEL ACCORDING TO ST. JOHN.

EDITED WITH NOTES AND DISSERTATIONS,

By B. F. WESTCOTT, D.D.,
Canon of Peterborough, and Regius Professor of Divinity at Cambridge.

Medium 8vo. 10*s.* 6*d.* [*Ready.*

(REPRINTED FROM THE SPEAKER'S COMMENTARY.)

THE APOCRYPHA.

WITH A COMMENTARY, EXPLANATORY & CRITICAL,

BY VARIOUS WRITERS.

Edited by Rev. HENRY WACE, M.A.,
Preacher of Lincoln's Inn, Professor of Ecclesiastical History, King's College, London.

2 *Vols. Medium 8vo.*

(UNIFORM WITH THE SPEAKER'S COMMENTARY.)

THE LIFE AND WRITINGS OF ST. JOHN THE DIVINE.

By the LORD BISHOP OF DERRY AND RAPHOE.

2 *Vols. 8vo.*

ITALIAN PRINCIPIA, Part II.

A FIRST ITALIAN READING-BOOK, CONTAINING FABLES, ANECDOTES, HISTORY, AND PASSAGES FROM THE BEST ITALIAN AUTHORS.

With Grammatical Questions, Notes, and a Copious Etymological Dictionary.

12mo.

LIFE OF JONATHAN SWIFT.

By HENRY CRAIK, B.A.,
Late Scholar and Snell Exhibitioner, Balliol College, Oxford.

8vo.

MUSIC IN ENGLAND

AND THE PROPOSED

ROYAL COLLEGE OF MUSIC.

THREE ADDRESSES DELIVERED BY

H.R.H. THE DUKE OF EDINBURGH, K.G.,

H.R.H. THE DUKE OF ALBANY, K.G.,

AND

H.R.H. PRINCE CHRISTIAN, K.G.

At the Free Trade Hall, Manchester, December 12th, 1881.

Post 8vo. 1*s.*

HYDROGRAPHICAL SURVEYING.

BEING A DESCRIPTION OF THE METHODS USED IN THE CONSTRUCTION OF MARINE CHARTS.

By Capt. W. J. L. WHARTON, R.N.,
Late in Command of H.M. Surveying Ships, "Sheerwater" and "Fawn."

With Illustrations. 8vo.

MR. MURRAY'S STUDENT'S MANUALS.

NEW VOLUMES.

THE STUDENT'S MANUAL OF ECCLESIASTICAL HISTORY.

A HISTORY OF THE CHRISTIAN CHURCH.

BOOK I.—TO THE ESTABLISHMENT OF THE HOLY ROMAN EMPIRE AND THE PAPAL POWER. A.D. 30—1380.

BOOK II.—THE MIDDLE AGES AND THE REFORMATION. A.D. 1381—1598.

By **PHILIP SMITH, B.A.**

With Woodcuts. 2 Vols. Post 8vo. 7*s*. 6*d*. each.

THE STUDENT'S MANUAL OF THE EVIDENCES OF CHRISTIANITY.

By **HENRY WACE, M.A.,**

Preacher at Lincoln's Inn; Professor of Ecclesiastical History, King's College, London.

Post 8vo.

"We are glad to hear that Mr. Wace is preparing for Mr. Murray's Student's Series a Manual of the Evidences of Christianity, a work long wanted, which could not be placed in better hands."—*Quarterly Review.*

THE STUDENT'S HISTORY OF THE ROMAN EMPIRE,

FROM THE ESTABLISHMENT OF THE EMPIRE TO THE ACCESSION OF COMMODUS, A.D. 180.

Post 8vo.

This Work will take up the History at the point at which Dean Liddell leaves off, and carry it down to the period at which Gibbon begins.

THE STUDENT'S HISTORY OF MODERN EUROPE,

FROM THE END OF THE MIDDLE AGES TO THE TREATY OF BERLIN, 1878.

Post 8vo.

THE STUDENT'S MANUAL OF THE GEOGRAPHY OF INDIA.

By **GEORGE SMITH, LL.D.,**
Author of the "Life of Dr. Wilson, Dr. Duff," &c.

Post 8vo.

MR. MURRAY'S HANDBOOKS.

NEW VOLUMES AND NEW EDITIONS.

HANDBOOK FOR TRAVELLERS IN THE BENGAL PRESIDENCY.

FROM CALCUTTA TO JAGHERNAULT ON THE SOUTH, ALLAHABAD ON THE WEST, DARJEELING ON THE NORTH, AND RANGOON ON THE EAST.

By **E. B. EASTWICK, C.B.,**
Author of the Handbooks to Madras and Bombay.

With Maps and Plans. Post 8vo.

HANDBOOK—YORKSHIRE:

DONCASTER, HULL, SELBY, BEVERLEY, SCARBOROUGH, WHITBY, HARROGATE, RIPON, LEEDS, WAKEFIELD, BRADFORD, HALIFAX, HUDDERSFIELD, SHEFFIELD.

New and Revised Edition. Map and Plans. Post 8vo.

HANDBOOK—WILTS, DORSET, AND SOMERSET:

SALISBURY, CHIPPENHAM, WEYMOUTH, SHERBORNE, WELLS, BATH, BRISTOL, TAUNTON, &c.

New and Revised Edition. Map. Post 8vo.

HANDBOOK FOR TRAVELLERS IN GREECE,

THE IONIAN ISLANDS, CONTINENTAL GREECE, ATHENS, THE PELOPONNESUS, THE ISLANDS OF THE ÆGEAN SEA, ALBANIA, THESSALY, AND MACEDONIA.

New and thoroughly Revised Edition. Maps. Post 8vo.

HANDBOOK—GLOUCESTER, HERE-FORD, AND WORCESTER:

CIRENCESTER, CHELTENHAM, STROUD, TEWKESBURY, LEO-MINSTER, ROSS, MALVERN, KIDDERMINSTER, DUDLEY, BROMSGROVE, EVESHAM.

New and Revised Edition. Map. Post 8vo.

HANDBOOK—NORTH WALES:

LLANGOLLEN, BANGOR, CARNARVON, BEAUMARIS, SNOWDON, LLANBERIS, BETTWS Y COED, DOLGELLY, CADER IDRIS, CONWAY, &c.

New and Revised Edition. Map. Post 8vo.

BRADBURY, AGNEW, & CO., PRINTERS, WHITEFRIARS.