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MAX PLANCK INSTITUTE
FOR THE HISTORY OF SCIENCE

Scientific Apparatus

Special Loan Collection 1876



SOUTH KENSINGTON MUSEUM

SCIENCE HANDBOOK

3/6.

Hrsg.:
Francis R. Sandford

SOUTH KENSINGTON MUSEUM SCIENCE HANDBOOKS.

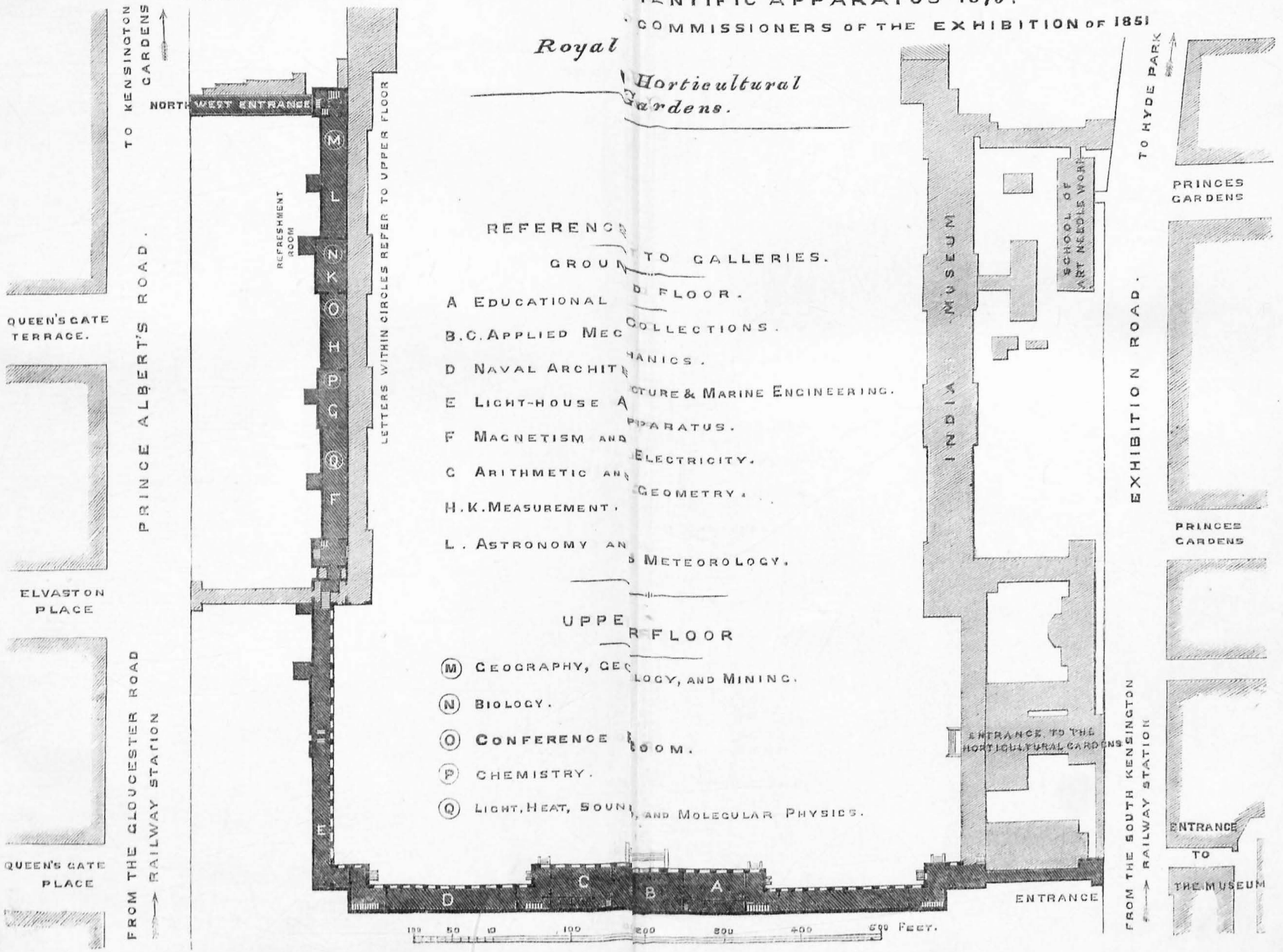
SPECIAL LOAN COLLECTION OF SCIENTIFIC APPARATUS

1876.

SOUTH KEN[SINGTON] MUSEUM.

LOAN COLLECTION OF SCIENTIFIC APPARATUS 1876.

PLAN OF GALLERIES LENT BY H.M. COMMISSIONERS OF THE EXHIBITION OF 1851



REFERENCE TO GALLERIES.

GROUND FLOOR.

A EDUCATIONAL COLLECTIONS.

B.C. APPLIED MECHANICS.

D NAVAL ARCHITECTURE & MARINE ENGINEERING.

E LIGHT-HOUSE APPARATUS.

F MAGNETISM AND ELECTRICITY.

G ARITHMETIC AND GEOMETRY.

H.K. MEASUREMENT.

L. ASTRONOMY AND METEOROLOGY.

UPPER FLOOR

(M) GEOGRAPHY, GEOLOGY, AND MINING.

(N) BIOLOGY.

(O) CONFERENCE ROOM.

(P) CHEMISTRY.

(Q) LIGHT, HEAT, SOUND, AND MOLECULAR PHYSICS.

SOUTH KENSINGTON MUSEUM.

HANDBOOK

TO THE

SPECIAL LOAN COLLECTION

OF

SCIENTIFIC APPARATUS

1876.



Prepared at the request of the Lords of the Committee of Council on Education, and Published for them

BY

CHAPMAN AND HALL, 193, PICCADILLY.



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INTRODUCTION.

By Minute dated 22nd January, 1875, the Lords of the Committee of Council on Education approved of a proposal to form a Loan Collection of Scientific Apparatus, which was to include not only apparatus for teaching and for investigation, but also such as possessed historic interest on account of the persons by whom, or the researches in which, it had been employed. Their Lordships then invited some of the leading men of science of the country—the Presidents of the learned Societies and others—to act on a Committee to consider the matter, and aid them with their advice. This Committee, to whose exertions the formation of the Collection is so largely due, consisted of

The Right Hon. the Lord Chancellor.
Professor F. A. Abel, F.R.S., President of the Chemical Society.
The Right Hon. Lord Aberdare, President of the Horticultural Society.
Capt. W. de W. Abney, R.E.
Professor H. W. Acland, M.D., F.R.S., President of the Medical Council of the United Kingdom.
Professor J. C. Adams, M.A., F.R.S.
Professor W. G. Adams, M.A., F.R.S.
Sir G. B. Airy, K.C.B., D.C.L., F.R.S., the Astronomer Royal.
Dr. G. J. Allman, F.R.S., President of the Linnæan Society.
Mr. J. Anderson, LL.D., C.E.
Mr. D. T. Ansted, M.A., F.R.S.
Professor E. Atkinson, Ph. D.
Professor R. Stawell Ball, LL.D., F.R.S.
Professor W. F. Barrett.
Rev. A. Barry, D.D.
Mr. W. B. Baskcomb.
Mr. H. Bauerman.
Mr. G. Bentham, F.R.S.
Mr. Hugh Birley, M.P.
Professor Bloxam.
Major Bolton.
Professor F. A. Bradley.
Mr. F. J. Bramwell, F.R.S.
Mr. T. Brassey, M.P.
Mr. H. W. Bristow, F.R.S.
Mr. C. Brooke, M.A., F.R.S.
Mr. G. Busk, F.R.S.
Major-General Cameron, C.B., F.R.S.
Dr. W. B. Carpenter, C.B., F.R.S.
Mr. C. O. F. Cator.

Mr. W. Chappell.
Mr. H. W. Chisholm, Warden of the Standards.
Lord Alfred Churchill, Chairman of Council of Society of Arts.
Mr. G. T. Clark.
Mr. Latimer Clark.
Professor R. Bellamy Clifton, M.A., F.R.S.
Sir Henry Cole, K.C.B.
Vice-Admiral Sir R. Collinson, K.C.B., Deputy Master of the Trinity House.
Dr. Debus, F.R.S.
Mr. Warren De La Rue, D.C.L., F.R.S.
Mr. G. Dixon, M.P.
Professor P. M. Duncan, M.B., F.R.S., President of the Geological Society.
Professor W. T. Thiselton Dyer, M.A., B. Sc.
Major-General F. Eardley-Wilmot, R.A., F.R.S.
Mr. H. S. Eaton, President of the Meteorological Society.
Sir P. De M. G. Egerton, Bart., M.P., F.R.S.
Mr. R. Etheridge, F.R.S.
Captain Evans, R.N., C.B., F.R.S., Hydrographer of the Navy.
Mr. J. Evans, F.R.S.
Professor W. H. Flower, F.R.S.
Mr. D. Forbes, F.R.S.
Professor G. Carey Foster, B.A., F.R.S., President of the Physical Society.
Professor Michael Foster, M.D., F.R.S.
Colonel Lane Fox, President of the Anthropological Institute.
Professor Frankland, Ph. D., D.C.L., F.R.S.
Mr. A. H. Garrod, M.A.
Dr. Gilbert, F.R.S.
Dr. J. H. Gladstone, F.R.S.
Mr. D. Glasgow.
Professor Goodeve, M.A.
Mr. A. C. L. G. Günther, M.A., M.D., F.R.S.
Professor Guthrie, Ph. D., F.R.S.
Mr. J. Baillie-Hamilton.
The Right Hon. Lord Hampton, G.C.B., F.R.S., President of the Institute of Naval Architects.
Mr. T. E. Harrison, President of the Institution of Civil Engineers.
Sir J. Hawkshaw, F.R.S.
Mr. T. Hawksley, President of the Institute of Mechanical Engineers.
The Hon. Alan Herbert.
Mr. J. Hick, M.P.
Dr. J. D. Hooker, C.B., President of the Royal Society.
Mr. J. Hopkinson, B.A., D. Sc.
Mr. W. Huggins, D.C.L., F.R.S., President of the Royal Astronomical Society.
Professor W. Hughes.
Professor T. H. Huxley, LL.D., Sec. R.S.
Lieut.-General Sir H. James, R.E., F.R.S.
Rev. J. H. Jellett, B.D.
Professor E. Ray Lankester, M.A., F.R.S.
Lord Lindsay, M.P.
Mr. J. Norman Lockyer, F.R.S.
Rev. R. Main, M.A., F.R.S.
Dr. R. J. Mann.
Mr. N. Story-Maskelyne, M.A., F.R.S.
Professor J. Clerk Maxwell, M.A., F.R.S.
Mr. C. W. Merrifield, F.R.S.
Professor Miller, M.A., LL.D., F.R.S.
Professor Morris.
Mr. A. J. Mundella, M.P.
Professor Odling, M.A., F.R.S.
Mr. W. K. Parker, F.R.S.
Dr. Percy, F.R.S.

Mr. J. A. Phillips.
The Right Hon. Lyon Playfair, C.B., M.P., F.R.S.
Dr. Pole, F.R.S.
Professor Prestwich, F.R.S.
Professor A. C. Ramsay, LL.D., F.R.S.
Major-General Sir H. C. Rawlinson, K.C.B., F.R.S., President of the Royal Geographical Society.
The Right Hon. Lord Rayleigh, F.R.S.
Professor A. W. Reinold, M.A.
Professor Roscoe, Ph. D., F.R.S.
The Right Hon. the Earl of Rosse, D.C.L., F.R.S.
Mr. G. W. Royston-Pigott, M.A., M.D., F.R.S.
Mr. J. Scott Russell, F.R.S.
Dr. W. J. Russell, F.R.S.
Professor W. Rutherford, M.D.
Mr. B. Samuelson, M.P.
Professor J. S. Burdon Sanderson, M.D., F.R.S.
Mr. T. Savage, M.A.
Mr. R. H. Scott, M.A., F.R.S.
Major Seddon, R.E.
Professor Shelley.
Sir. J. P. Kay-Shuttleworth, Bart.
Mr. C. W. Siemens, D.C.L., F.R.S.
Professor H. J. S. Smith, M.A., F.R.S.
Mr. W. Warington Smyth, M.A., F.R.S.
Mr. H. C. Sorby, F.R.S., President of the Royal Microscopical Society.
Mr. W. Spottiswoode, M.A., Treasurer Royal Society.
Mr. G. R. Stephenson.
Professor Balfour Stewart, LL.D., F.R.S.
Dr. W. H. Stone.
Major - General Strachey, C.S.I., F.R.S.
Lieut.-Col. Strange, F.R.S.
Professor P. G. Tait, M.A.
Mr. J. Torr, M.P.
Rev. J. F. Twisden, M.A.
Professor Tyndall, LL.D., F.R.S.
Professor W. C. Unwin, B. Sc.
Mr. C. V. Walker, F.R.S., President of Society of Telegraphic Engineers.
Mr. F. H. Wenham.
Sir C. Wheatstone, F.R.S. (since deceased).
Sir. J. Whitworth, Bart., F.R.S.
Professor Williamson, Ph. D., F.R.S.
Mr. Bennet Woodcroft, F.R.S.
Dr. J. Woolley.
Colonel H. Stuart Wortley.

The first meeting of this Committee was held on the 13th February, 1875; the number of those who were present showing the interest already felt in the subject. The Lord President of the Council, the Duke of Richmond, and the Vice-President, Viscount Sandon, in explaining the objects of the Collection, took occasion to refer to the recommendations of the Royal Commission on Scientific Instruction, with regard to the creation of a Science Museum.

Their Lordships stated their conviction that the development of the Educational, and certain other Departments of the South Kensington Museum, and their enlargement into a Museum

somewhat of the nature of the *Conservatoire des Arts et Métiers* in Paris, and other similar institutions on the Continent, would tend to the advancement of science, and be of great service to the industrial progress of this country. While expressing their hope that the Loan Collection might forward this desirable object, their Lordships guarded themselves against committing Her Majesty's Government, which had not yet fully considered the subject, to any definite scheme.

On the motion of the President of the Royal Society, Dr. Hooker, it was unanimously resolved by the meeting that an exhibition such as that proposed would be most instructive and valuable.

The question of the limits of the collection were discussed, and Sub-Committees were appointed to consider the limitations it might be desirable to place on the term "scientific apparatus" in the respective sections, while bearing in mind the space disposable for the exhibition in the Museum. As a provisional arrangement five Sub-Committees of sections were appointed to whom it was left to suggest such modifications in classification as might be found advisable.

The sections were—

1. Mechanics (including pure and applied mathematics).
2. Physics.
3. Chemistry (including metallurgy).
4. Geology, Mineralogy, and Geography.
5. Biology.

The Committees for the several sections are given at page xxv.

The question of classification, having been carefully considered at numerous meetings of these Sub-Committees, was brought before the general Committee on the 12th May, and the several schemes were referred to a special Sub-Committee, formed of three members from each sectional Sub-Committee. It was also decided to postpone the exhibition, which it was originally intended to open in June, 1875, to March, 1876. The large number

of objects sent from abroad, and the late period of their arrival, have necessitated a further postponement of the opening to May, 1876.

The Sub-Committee appointed to revise and report on the classification of the Collection after three meetings, under the chairmanship of the President of the Royal Society, submitted a scheme of classification to the General Committee on June 22nd. After having been carefully considered, it was, with some slight alterations, approved, and is given at page xix. This programme was immediately issued, and the classification into sections is that adopted for the catalogue and exhibition, though the nature of the Galleries has necessitated some alteration in the order of the sections.

It had been the intention from the first to give the Loan Collection an International character, so as to afford men of science and those interested in education an opportunity of seeing what was being done by other countries than their own in the production of apparatus, both for research and for instruction—an opportunity which it was hoped would be of advantage also to the makers of instruments. As soon therefore as the programme had been definitely settled, steps were taken to interest foreign countries in the Exhibition; and it was determined to obtain the co-operation of men of science on the Continent, who, while acting as members of the General Committee, should form special Sub-Committees charged with the due representation of the science of their respective countries.

It was necessary to take special precautions to prevent misunderstanding as to the character of the Collection. The mention of internationality at once suggested the idea of an International Exhibition similar in its character and arrangements to the numerous Industrial Exhibitions which have been held in various countries. A wrong impression of this kind would have entailed serious inconvenience.

In International Exhibitions a certain amount of space is allotted to each country. These spaces are then divided by the Commis-

sioners of each country among its exhibitors, who display their objects—subject to certain general rules of classification—as they consider most advantageous, retaining the custody of their own property. The expenses of transport, arrangement, etc., are borne by the countries who exhibit. And the Exhibitions appeal naturally, more or less exclusively, to the industrial or trade-producing interests of those countries.

This was not the idea of the proposed Loan Collection at South Kensington. For that Collection it was desired to obtain not only apparatus and objects from manufacturers, but also objects of historic interest from museums and private cabinets, where they are treasured as sacred relics, as well as apparatus in present use in the Laboratories of Professors. The transport of all objects was undertaken by the English Government, and they were to be handed over absolutely to the custody of the Science and Art Department for exhibition; the arrangement being not by countries but strictly according to the general classification.

So soon as the object and scope of the Collection were thoroughly understood, the Committee of Council on Education met with the most gratifying responses to their invitations, which were communicated officially through the Foreign Office. Her Majesty's Ministers at Paris, Berlin, St. Petersburgh, Vienna, Florence, Brussels, the Hague, Stockholm, Madrid, Berne, and Washington, have personally interested themselves in the matter; and the Foreign Governments have afforded every facility and encouragement in forwarding this strictly international undertaking. The subjoined list of the foreign members of the General Committee speaks for itself, by the eminence and European reputation of its members.

BELGIUM.

M. Stas, Membre de l'Académie Royale (President).

M. le Général Brialmont, Président de l'Académie Royale et Inspecteur Général du Génie.

M. Dewalque, Membre de l'Académie Royale, Professeur de Géologie et de Minéralogie à l'Université de Liége.

M. Maus, Membre de l'Académie, Inspecteur Général des Ponts et Chaussées.
M. Plateau, Membre de l'Académie Royale, F.R.S.
M. Schwann, Membre de l'Académie Royale, Professeur à l'Université de Liége.
M. Van Beneden, Membre de l'Académie et Professeur à l'Université de Louvain, F.R.S.
M. le Général Liagre, Secrétaire perpétuel de l'Académie Royale, et Commandant et Directeur des Études de l'École Militaire (Secretary).

FRANCE.

M. le Général Arthur Jules Morin, Membre de l'Académie des Sciences, Directeur du Conservatoire des Arts et Métiers (President).
M. Alexre. Edmond Becquerel, Membre de l'Académie des Sciences, Professeur au Conservatoire des Arts et Métiers, F.R.S.
M. Henri Marie Bouley, Membre de l'Académie des Sciences, Inspecteur Général des Écoles Vétérinaires.
M. Gabriel Auguste Daubrée, Membre de l'Académie des Sciences, Directeur de l'École des Mines.
M. Jean Louis Armand de Quatrefages de Bréau, Membre de l'Académie des Sciences, Professeur au Museum d'Histoire Naturelle.
M. Jean Baptiste Dumas, Secrétaire Perpétuel de l'Académie des Sciences, F.R.S.
M. Hervé Auguste Etienne Albans Faye, Membre de l'Académie des Sciences, Président du Bureau des Longitudes.
M. Edmond Frémy, Membre de l'Académie des Sciences, Professeur au Museum d'Histoire Naturelle.
M. Jules Célestin Jamin, Membre de l'Académie des Sciences, Professeur à l'École Polytechnique.
M. Urbain Jean Joseph La Verrier, Membre de l'Académie des Sciences, Directeur de l'Observatoire, F.R.S.
M. Eugène Melchior Peligot, Membre de l'Académie des Sciences, Directeur des Essais à la Monnaie.
M. Henri Edouard Tresca, Membre de l'Académie des Sciences, Sous-Directeur du Conservatoire des Arts et Métiers (Secretary).

GERMANY.

I.—Berlin Committee.

Dr. A. W. Hofmann, Professor of Chemistry, F.R.S. (President).
Dr. Beyrich, Professor of Geology.
Dr. du Bois-Reymond, Professor of Physiology.
Dr. Dove, Professor of Physics, F.R.S.
Dr. Förster, Director of the Observatory.
Dr. Hagen, President of the Board of Works.
T. G. Halske, Telegraphic Engineer.
Dr. Hauchecorne, Director of the School of Mines.

Dr. Helmholtz, Professor of Physics, F.R.S.
Dr. Kiepert, Professor of Geography.
Dr. G. Kirchhoff, Professor of Physics, F.R.S.
Dr. Kronecker, Professor of Mathematics.
Dr. C. D. Martius, Chemist.
Von Morozowicz, General.
Dr. Neumayer, Hydrographer of the Imperial Admiralty.
Dr. Reuleaux, Director of the Polytechnic Academy.
Dr. Shellbach, Professor of Mathematics.
Dr. W. Siemens, Telegraphic Engineer.
Dr. Virchow, Professor of Pathology.
Dr. C. H. Vogel, Astronomer.
Dr. Websky, Professor of Mineralogy.

II.—COMMITTEE REPRESENTING OTHER CITIES AND TOWNS OF GERMANY.

Dr. Von Babo, Professor of Chemistry, Freiburg.
Dr. Beetz, Professor of Physics, Munich.
Dr. Buff, Professor of Physics, Giessen.
Dr. Clausius, Professor of Physics, Bonn, F.R.S.
His Excellency Dr. Von Dechen, Director of the Mining Department, Bonn.
Dr. Von Fehling, Professor of Chemistry, Stuttgart.
Dr. Von Feilitzsch, Professor of Physics, Greifswald.
Dr. Graebe, Professor of Chemistry, Königsberg.
Dr. Von Groddeck, Director of the School of Mines, Klausthal.
Dr. Heeren, Professor of Chemistry, Hanover.
Dr. Hittorf, Professor of Chemistry, Münster.
Dr. Karsten, Professor of Physics, Kiel.
Dr. Karsten, Professor of Physics, Rostock.
Dr. Knapp, Professor of Chemistry, Braunschweig.
Dr. Knoblauch, Professor of Physics, Halle.
Dr. Kölliker, Professor of Physiology, Würzburg, F.R.S.
Dr. Kundt, Professor of Physics, Strasburg.
Dr. Launhardt, Director of the Polytechnic School, Hanover.
Dr. Möhl, Cassel.
Dr. Poleck, Professor of Chemistry, Breslau.
Dr. Preyer, Professor of Physiology, Jena.
Dr. Von Quintus-Icilius, Professor of Physics, Hanover.
Dr. Reusch, Professor of Physics, Tübingen.
Dr. Romberg, Professor in the Nautical School, Bremen.
Dr. Rosenthal, Professor of Physiology, Erlangen.
Dr. Rümker, Director of the Observatory, Hamburg.
Dr. Serlo, Director of the Mining Department, Breslau.
Dr. C. Von Siemens, Professor in the Agricultural Academy, Hohenheim.
His Excellency Dr. Von Steinbeis, President, Stuttgart.
Dr. W. Weber, Professor of Physics, Göttingen, F.R.S.
Dr. Wiedemann, Professor of Physical Chemistry, Leipzig.
Dr. Winkler, Professor of Metallurgy, Freiberg.
Dr. Wöhler, Professor of Chemisty, Göttingen, F.R.S.

Dr. Wüllner, Professor of Physics, Aachen.
Dr. Zeuner, Director of the Polytechnic School, Dresden.
Dr. Zetzsche, Director of the Polytechnic School, Chemnitz.

ITALY.

Il Com. Blaserna, Professor of Physics and Rector of the Royal University of Rome.
Il Com. Cantoni, Professor of Physics at the Royal University of Pavia.
Il Cav. Respighi, Professor of Astronomy in the Royal University of Rome, and Director of the Observatory of the Campidoglio.

THE NETHERLANDS.

Professor Dr. P. L. Rijke, Conseiller d'État (President).
Professor Dr. H. G. de Sande Bakhuyzen.
Professor Dr. C. H. D. Buys Ballot.
Professor Dr. J. Bosscha.
Professor Dr. F. C. Donders, F.R.S., President of the Royal Academy of Science, Amsterdam.
Professor Dr. J. W. Gunning.
Professor Dr. R. A. Mees.
Professor Dr. V. S. M. Van der Willigen.
Dr. D. de Loos, Director of the Secondary Town-School of Leyden (Secretary).

NORWAY.

Professor Esmark.
Herr Mohn, Director of the Meteorological Institute of Norway.
Professor Waage.

RUSSIA.

M. Struve, Conseiller Privé Directeur de l'Observatoire Central Nicolas (President).
M. Ovsiannikow, membre de l'Académie.
M. Gadolin, membre de l'Académie.
M. Gruber, Professeur de l'Académie de Médécine et de Chirurgerie.
M. Stubendorf, Colonel d'État-Major.
M. Wyschnegradsky, Professeur de l'Institut technologique.
M. Beilstein, Professeur de l'Institut technologique.
M. Barbot de Marny, Professeur de l'Institut des Mines.
M. Koulibine, Professeur de l'Institut des Mines.

SWITZERLAND.

Professor E. Wartmann (President).
Professor J. Amsler Laffon.
Professor D. Colladon-Ador.
Professor Dr. F. A. Forel.
Professor Dr. E. Hagenbach-Bischoff.
Professor Ad. Hirsch.
Professor Albert Mousson.
M. E. Sarasin-Diodati.
Professor L. Soret.
Colonel Gautier (Secretary).

AUSTRIA AND HUNGARY.

The Minister of Public Instruction has appointed Sectionschef Fidler to organize the contributions from these countries.

SPAIN.

No Committee has been formed, but the Government has promised to contribute, and Señor Riano has been specially appointed to make the necessary arrangements.

UNITED STATES.

The Government has, through Mr. Fish, replied that it is in communication with the various Departments and Scientific Institutions with the object of forwarding the Exhibition.

When men of this position in all branches of Science have given their adhesion to the programme of such an exhibition, its success might well be considered as secured. But these gentlemen did not rest satisfied with merely giving their names in recognition of its value: they have spared no time and labour in making the undertaking a real success. And the Lords of the Committee of Council on Education feel assured that, in offering them their thanks for their invaluable services, they convey not only their own sentiments but the grateful recognition of their labours by a country at large.

It will be readily understood from what has been said of the nature, scope, and method of the exhibition, that a large staff was required, in addition to the permanent staff of the Museum, to organise and arrange the collection in the limited time which could be afforded for that purpose. Special arrangements had, therefore, to be made; and their Lordships have great satisfaction in recording the names of those gentlemen who have rendered very valuable services,—many of them as volunteers—greatly aiding the staff of the Museum in their laborious duties. These were Captain Abney, R.E.; Dr. Atkinson; Mr. Bartlett; Dr. Brunton; Dr. Biedermann; Professor Crum-Brown; Captain Fellowes, R.E.; Professor Carey-Foster; Dr. Michael Foster; Herr Kirchner; Professor Goodeve; Dr. Guthrie; Commander

T. A. Hull, R.N.; Mr. Iselin; Mr. Judd; Mr. Norman Lockyer; Dr. R. J. Mann; Mr. Clements Markham; Professor H. McLeod; Professor Roscoe; Professor Shelley; Dr. Burdon Sanderson; Dr. Schuster; Dr. Voit; and Mr. R. Wylde.

To those men of science who, in this matter and in the work of the general Committee and Sub-Committees, have given much valuable time, and have afforded them the benefit of their great knowledge and experience, the Lords of the Committee of Council on Education feel their best thanks are due, and they trust that the immediate success and future results of the Exhibition, which owes so much to them, will reward them for the labours which they have ungrudgingly devoted to it.

In order to make the Exhibition as useful and interesting as possible, a handbook containing introductory notices to the several sections has been prepared. For writing these notices the Lords of the Committee of Council on Education have been fortunate in securing the services of gentlemen the mention of whose names will be a sufficient indication of the character of the work. These gentlemen are

Captain W. de W. Abney, R.E.
Professor W. Kingdon Clifford, M.A., F.R.S.
Captain J. E. Davis.
Professor G. Carey Foster, B.A., F.R.S.
Professor Geikie, F.R.S.
Professor Goodeve, M.A.
Professor Guthrie, F.R.S.
Professor T. H. Huxley, LL.D., Sec. R.S.
Mr. J. Norman Lockyer, F.R.S.
Professor McLeod.
Mr. Clements R. Markham, C.B., F.R.S.
Mr. N. Story Maskelyne, M.A., F.R.S.
Professor J. Clerk Maxwell, M.A., F.R.S.
Mr. R. H. Scott, M.A., F.R.S.
Professor H. J. S. Smith, M.A., F.R.S.
Mr. W. Warington Smyth, M.A., F.R.S.
Mr. H. C. Sorby, F.R.S.
Mr. W. Spottiswoode, M.A., F.R.S.
Dr. W. H. Stone.
Professor P. G. Tait, M.A.

It had been originally proposed to exhibit the collection of Scientific Apparatus in the South Kensington Museum; but

various circumstances, which could not be foreseen, having rendered it necessary to abandon this intention, Her Majesty's Commissioners for the Exhibition of 1851 most liberally placed the galleries on the western side of the Horticultural Gardens at the disposal of the Science and Art Department for the purpose of the exhibition. Though, unfortunately, these galleries are disconnected from the Kensington Museum, they are admirably adapted to the present purpose, and afford an accommodation which could not otherwise have been obtained.

(By order)

F. R. SANDFORD,

Secretary, Committee of Council on Education.

CLASSIFICATION OF THE COLLECTION.

ARITHMETIC.

Apparatus for teaching arithmetic.—Calculating machines.—Instruments for solving equations.—Slide rules.—Numbering and enumerating apparatus, &c.

GEOMETRY.

Instruments used in geometrical drawing.—Methods of copying.—Pantigraph, micrograph.—Peaucellier's cell and parallel motion.—Machines for description of curves and specimens of the curves they describe, including geometric turning.—Instruments for giving graphic representations of phenomena.—Models to illustrate descriptive geometry.—Specimens to illustrate the process of making models according to a design.—Models to illustrate solid geometry, perspective, crystallography, &c.—Stereoscopic illustrations of solid geometry.

MEASUREMENT.

Of length.—Standard yard, metre, &c.—Comparator for standards of length (sight and touch).—Gauges, measuring wheels, steel tapes, &c.—Micrometers and verniers.—Cathetometers.

Of area.—Planimeters, &c.

Of volume.—Standard gallon, litre, &c.—Pipettes, burettes.—Meters for gas, water, &c.

Of angles.—Divided circles, theodolites, clinometers, goniometers, &c.

Of mass.—Standard pound, kilogramme, &c.—Vacuum and other balances.

Of density.—Specific gravity bottles, areometers, &c.

Of time.—Clocks and pendulums, chronometers, watches, and balance wheels.—Tuning forks for measuring small intervals of time.—Chronographs.

Of velocity.—Such as Morin's machine.—Strophometers, current meters, ships' logs, &c.

Of momentum.—Ballistic apparatus.

Of force.—Spring balances, pressure gauges, torsion balances, &c.

Of work.—Indicators, dynamometers, &c.

KINEMATICS, STATICS, AND DYNAMICS.

Elementary Illustrations.—Position and displacement of a point, a rigid body or a material system.—Composition and resolution of displacements.—Velocity and acceleration, their composition and resolution.—Displacements of a connected system.—Principles of mechanism.—Rolling contact, sliding contact, belting, link connections, shafting, universal joints, &c.—Transmission of work. —Relation between the displacement of two pieces of a machine and the forces which they transmit.—The mechanical powers.—Instruments for illustrating the laws of motion, such as pendulums, gyroscopes, dynamical tops.

Laws of fluid pressure ; stability of floating bodies.

Discharge of fluids through orifices, and their motion in channels.

Hydraulic and pneumatic transmission of power.

MOLECULAR PHYSICS.

Instruments and apparatus employed in teaching, and in the investigations and observations connected with :—

Pressure on Matter.—Tension, compression (piezometer), torsion, flexion ; relation of volume to pressure ; elasticity of liquids and gases.—Hardness (of solids and liquids), toughness, brittleness, malleability, &c.

Communication of Pressure through Fluids.—Pressure of air, its consequences and applications.—Barometers, air-pumps, siphons, suction-pumps, spirators, &c. ; Pressure of water, its consequences and applications.—Levels, side pressure, &c.

Density.—Methods of measuring densities of gases, vapours, liquids, solids.

Adhesion and Cohesion.—Condensation of gases in solids, solution of gases in liquids, mixing of gases with gases (diffusion, transpiration, &c.), absorption of liquids by solids (capillarity, &c.), absorption of liquids by gases (evaporation, &c.), mixing of liquids with liquids (Osmose, Diffusion Dialysis).—Evaporation of solids, solution of solids, mixture of solids with solids (cementation, &c.).

SOUND.

Instruments and apparatus employed in teaching, and in the investigations and observations connected with :—

Geometrical, Mechanical, and Optical methods of Illustrating the Laws of Wave-Motion.—Progressive waves, composition of vibrations, interference, stationary waves.

Generation of Sound.—Fog-horn, &c.

Conduction of Sound.—Through solids, liquids, and gases, stethoscopes.

Velocity of Sound.

Detection of Sound.—Sensitive flame, &c.

Reflection and Refraction.—Ear trumpets, acoustic lenses, &c.

Dispersion and Absorption.

Musical Sounds.—Pitch, standards of pitch, standard tuning forks, &c. ; methods of measuring and comparing rates of vibration ; toothed wheels,

Syrens, &c.; vibration microscopes, &c.; methods of illustrating the nature of musical intervals; manometric flames, mirrored tuning forks, &c.

Musical Quality.—Illustrations of the different] quality of the sounds of various instruments, harmonics, and overtones, resultant tones, instruments for studying quality, resonators, phonautographs, &c.

Musical Instruments Illustrating the above.—Methods of exhibiting the mode of vibration of various instruments and the quality of the sounds yielded by them.

LIGHT.

Instruments and apparatus employed in teaching, and in the investigations and observations connected with :—

Production.—Combustion, electric discharge, &c.

Measurement of intensity, velocity.

Action of Matter on Light.—Reflexion, refraction, dispersion, achromatism, direct vision prisms, polarisation, absorption (colour), fluorescence, &c.

Action of Light on Light.—Interference, diffraction, measurement of wave length (optical banks), &c.

Action of Light on Matter.—Photography, radiometry, phosphorescence, &c.

Technical Applications of Optical Principles.—Lighthouse.—Illumination, &c.

HEAT.

Instruments and apparatus employed in teaching, and in the investigations and observations connected with :—

Sources of Heat.—Chemical, electrical, dynamical, solar, calorescence, &c.

Effects of Heat on Matter.—Changes of temperature, expansion and change of elasticity, liquefaction, vaporization, &c.

Measurement of Temperature.—Thermometers, pyrometers, &c.

Propagation of Heat.—Radiant heat,—Radiometer, reflection, refraction, radiation, absorption, polarization; Conduction,—Solids, liquids, gases; Convection,—Ventilation, &c.

Effect of change of Molecular State on Temperature.—Freezing mixtures, ice machines, &c.

Effect of change of Pressure and Volume.

Heat Quantity.—Unit of heat, calorimeters, specific heat, &c.—Methods of determining latent heat.

Mechanical Equivalent of Heat—Methods of determining.—Illustrations of thermodynamics.

Electrical Equivalent of Heat.—Methods of determining.

Analysis of Solar Radiation.

MAGNETISM.

Instruments and apparatus employed in teaching, and in the investigations and observations connected with :—

Natural Magnets.
Permanent Artificial Magnets.
Electro-Magnets.
Methods of Magnetization.—Effects of Magnetization. Conditions affecting intensity of Magnetization :—Temperature (chemical), composition, strains, &c.
Magnetic Induction of all Substances.—Diamagnetism.
Measurement of intensity of magnetization, magnetic moment.
Terrestrial Magnetism.—Instruments for observation and automatic registration of the magnetic elements.

ELECTRICITY.

Instruments and apparatus employed in teaching, and in the investigations and observations connected with :—

Production and Maintenance of Difference of Potential.—Electrical machines acting by friction, induction (doublers, replenishers, &c., Holz's and Töppler's machines, &c.); galvanic batteries; thermo-electric piles; magneto-electric machines.—Other sources, such as pyro-electricity, pressure electricity, cleavage, capillarity, osmose, &c.

Detection and Measurement of Difference of Potential.—Electroscopes, electrometers, standards of electro-motive force, methods of comparison.

Accumulation of Electricity.—Insulators, condensers, accumulators, effects due to accumulated electricity, distribution on conductors, polarisation of dielectrics, &c.

Measurement and Electric Quantity.—Torsion balances, standard accumulators, methods of comparing electric capacities and dielectric coefficients.

Detection of Measurement of Electric Currents.—Galvanoscopes, galvanometers, voltameters, electro-dynamometers, &c.

Resistance.—Standards of resistance, methods of comparing resistances, methods of establishing absolute standards (British Association unit appar.).

Effects of Electric Currents.—Production of light, heat, electrolysis, electro-diffusion.—Action on magnets, soft iron (electro-magnets), action of currents on currents.

Technical Application of Electricity.—Electric telegraph, &c.

ASTRONOMY.

Star maps, catalogues, globes, orreries, &c.
Meridian instruments.
Arrangements for communicating true time,
Altazimuths, zenith-sectors, sextants, &c.
Equatoreal telescopes { reflectors. refractors.
Micrometers.
Driving clocks.
Special arrangements for—
Celestial photography.
Spectroscopic observations.
Thermo-electric observations.
Siderostats.

APPLIED MECHANICS.

As the Exhibition must be regarded as chiefly referring to education, research, and other scientific purposes, it must in this division consist principally of models, diagrams, mechanical drawings, and small machines, illustrative of the principles and progress of mechanical science, and of the application of mechanics to the arts.

Properties of Materials.
Structures at rest and in motion.
Prime movers.
Reservoirs of energy.
Regulators.
The application of the principles of mechanics to machinery as used in the arts.
Shipping, naval architecture, and marine engineering.

CHEMISTRY.

Scientific instruments, apparatus, and materials employed in the investigation and teaching of chemical science, and in the application of its principles to scientific purposes.

Diagrams and models.
Illustrations of analytical results.
Specimens of chemicals,—(*a*), organic, (*b*) mineral.
Apparatus and fittings for laboratory and lectures.
Apparatus for gravimetric and volumetric operations.
Apparatus for distillation and filtration.
Apparatus for operations by the dry or hot method, such as furnace, blowpipe, &c.
Refrigeratory apparatus.
Apparatus for spectrum analysis.

NOTE.—Operations of the following nature may be illustrated, viz. :—

Organic analysis.
Mineral analysis.
Electrolysis.
Water analysis.
Gas analysis.
Spectrum analysis.
Methods of investigation connected with vegetation and respiration.

METEOROLOGY.

Thermometers and barometers, of special construction.
Anemometers, rain gauges, hydrometers, &c.
Self-recording meteorological apparatus.
Illustrations of various systems of storm signals.
Weather maps.
Instruments illustrating the phenomena of atmospheric electricity.
Instrument stands.

GEOGRAPHY.

Instruments used in surveying.

Instruments used in geodesy and hydrography, including hypsometrical instruments, tide gauges, &c.

Projections, maps, charts, models, and globes.

Deep-sea sounding apparatus.—Seismographical instruments.

GEOLOGY AND MINING.

Instruments for field and underground surveying.

Typical collections of rock specimens, including vein stones.

Typical fossils arranged stratigraphically.

Maps in different stages, and finished maps.

Geological models, horizontal and vertical sections.

Diagrams and plates of fossils, and general geological diagrams used in lecture rooms.

Microscopic sections of rocks and minerals, and apparatus for cutting such sections.

Anemometers, water gauges, mining barometers, and thermometers.

Mining plans, sections and models of workings.

MINERALOGY, CRYSTALLOGRAPHY, ETC.

Goniometers.

Apparatus for studying and exhibiting the optical characters of crystals.

Sections for optical examination.

Blowpipe and other portable apparatus for determining minerals.

Collections of crystals, models of crystals, plates of crystals, and apparatus for drawing them.

Educational collections of minerals, &c.

Diagrams and models for lecture rooms.

BIOLOGY.

1. Microscopes with accessory apparatus for biological research, &c.
2. Physiological apparatus for investigating—
   - *a*. The growth and mechanical movements of living organisms and their parts.
   - *b*. The chemical phenomena of living organisms.
   - *c*. The electrical phenomena of living organisms.
   - *d*. The functions of the nervous and other systems.
3. Apparatus for anatomical research.
4. Apparatus for collecting and preserving objects of natural history.
5. Appliances for teaching biology.

A limited number of examples illustrating the performances of the apparatus will be admissible.

SUB-COMMITTEES OF SECTIONS.

Section I.—Mechanics, including Pure and Applied Mathematics and Mechanical Drawing.

Professor J. C. Adams, M.A., F.R.S.
Mr. J. Anderson, LL.D., C.E.
Professor R. Stawell Ball, LL.D., F.R.S.
Rev. A. Barry, D.D.
Mr. W. B. Baskcomb.
Mr. Hugh Birley, M.P.
Major Bolton.
Professor F. A. Bradley.
Mr. F. J. Bramwell, F.R.S.
Mr. T. Brassey, M.P.
Mr. H. W. Chisholm, Warden of the Standards.
Mr. G. T. Clark.
Mr. Latimer Clark.
Professor R. B. Clifton, M.A., F.R.S.
Sir Henry Cole, K.C.B.
Mr. G. Dixon, M.P.
Major-General F. Eardley-Wilmot, R.A., F.R.S.
Mr. D. Glasgow.
Professor T. M. Goodeve, M.A.
The Right Hon. Lord Hampton, G.C.B., F.R.S., President of the Institute of Naval Architects.
Mr. T. E. Harrison, President of the Institute of Civil Engineers.
Sir J. Hawkshaw, F.R.S.
Mr. T. Hawksley, President of the Institute of Mechanical Engineers.
Mr. J. Hick, M.P.
Professor J. C. Maxwell, M.A., F.R.S.
Mr. C. W. Merrifield, F.R.S.
Mr. A. J. Mundella, M.P.
Dr. Pole, F.R.S.
The Right Hon. Lord Rayleigh, F.R.S.
Mr. J. Scott Russell, F.R.S.
Major Seddon, R.E.
Professor Shelley.
Mr. C. W. Siemens, D.C.L., F.R.S.
Professor H. J. S. Smith, M.A., F.R.S.
Mr. G. R. Stephenson.
Professor P. G. Tait, M.A.
Mr. J. Torr, M.P.
Rev. J. F. Twisden, M.A.
Professor W. C. Unwin, B.Sc.
Sir C. Wheatstone, F.R.S. (since deceased).
Sir J. Whitworth, Bart., F.R.S.
Mr. Bennet Woodcroft, F.R.S.
Dr. J. Woolley.
Colonel H. Stuart Wortley.

Section II.—Physics.

Capt. W. de W. Abney, R.E.
Professor W. G. Adams, M.A., F.R.S.
Sir G. B. Airy, K.C.B., D.C.L., F.R.S., Astronomer Royal.
Professor E. Atkinson, Ph. D.
Professor R. Stawell Ball, LL.D., F.R.S.
Professor W. F. Barrett.
Mr. C. O. F. Cator.
Mr. W. Chappell.
Professor R. B. Clifton, M.A., F.R.S.
Vice-Admiral Sir R. Collinson, K.C.B., Deputy Master of the Trinity House.
Dr. Debus, F.R.S.
Mr. Warren De La Rue, D.C.L., F.R.S.
Mr. H. S. Eaton, President of the Meteorological Society.
Professor G. Carey Foster, B.A., F.R.S., President of the Physical Society.
Dr. J. H. Gladstone, F.R.S.

Professor Guthrie, Ph.D., F.R.S.
Mr. J. Baillie-Hamilton.
Mr. J. Hopkinson, B.A., D. Sc.
Mr. W. Huggins, D.C.L., F.R.S., President of the Royal Astronomical Society.
Lord Lindsay, M.P.
Mr. J. Norman Lockyer, F.R.S.
Reverend R. Main, M.A., F.R.S.
Dr. R. J. Mann.
Mr. C. W. Merrifield, F.R.S.
Dr. Pole, F.R.S.
The Right Hon. Lord Rayleigh, F.R.S.
Professor A. W. Reinold, M.A.
Earl of Rosse, D.C.L., F.R.S.
Mr. R. H. Scott, M.A., F.R.S.
Mr. W. Spottiswoode, M.A., F.R.S.
Dr. W. H. Stone.
Lieut.-Colonel Strange, F.R.S.
Professor P. G. Tait, M.A.
Professor Tyndall, LL.D., F.R.S.
Mr. C. V. Walker, F.R.S., President of Society of Telegraphic Engineers.
Sir C. Wheatstone, F.R.S. (since deceased).
Dr. Woolley.

SECTION III.—CHEMISTRY.

Professor F. A. Abel, F.R.S., Chemist to the War Department.
Professor Bloxam.
Sir Henry Cole, K.C.B.
Mr. Warren De La Rue, D.C.L., F.R.S.
Professor Frankland, Ph.D., D.C.L., F.R.S.
Dr. Gilbert, F.R.S.
Dr. J. H. Gladstone, F.R.S.
Professor Odling, M.A., F.R.S., President of the Chemical Society.
Dr. Percy, F.R.S.
Mr. J. A. Phillips.
The Right Hon. Lyon Playfair, Ph.D., C.B., M.P., F.R.S.
Professor Roscoe, Ph.D., F.R.S.
Dr. W. J. Russell, F.R.S.
Professor Williamson, Ph.D., F.R.S.

SECTION IV.—PHYSICAL GEOGRAPHY, GEOLOGY, AND MINERALOGY.

Mr. D. T. Ansted, M.A., F.R.S.
Mr. H. Bauerman.
Professor F. A. Bradley.
Mr. H. W. Bristow, F.R.S.
Major-General Cameron, C.B., F.R.S.
Vice-Admiral Sir R. Collinson, K.C.B., Deputy Master of the Trinity House.
Professor P. M. Duncan, M.B., F.R.S., President of the Geological Society.
Sir P. De M. G. Egerton, Bart., M. P F.R.S.
Mr. R. Etheridge, F.R.S.
Captain Evans, R.N., C.B., F.R.S. Hydrographer of the Navy.
Mr. J. Evans, F.R.S.
Mr. D. Forbes, F.R.S.
Professor Hughes.
Lieut.-General Sir H. James, R.E., F.R.S.
Mr. N. Story-Maskelyne, M.A., F.R.S.
Mr. C. W. Merrifield, F.R.S.
Professor Miller, M.A., LL.D., F.R.S.
Professor Morris.
Professor Prestwich, F.R.S.
Professor A. C. Ramsay, LL.D., F.R.S.
Major-General Sir H. C. Rawlinson, K.C.B., F.R.S., President of the Royal Geographical Society.
Mr. W. Warington Smyth, M.A., F.R.S.

Mr. H. C. Sorby, F.R.S., President of the Royal Microscopical Society.

Major-General R. Strachey, C.S.I. F.R.S.

SECTION V.—BIOLOGY.

The Right Hon. Lord Aberdare, President of the Royal Horticultural Society.

Professor H. W. Acland, M.D., F.R.S., President of the Medical Council of the United Kingdom.

Dr. G. J. Allman, F.R.S., President of the Linnæan Society.

Mr. G. Bentham, F.R.S.

Mr. C. Brooke, M.A., F.R.S.

Mr. G. Busk, F.R.S.

Dr. W. B. Carpenter, C.B., F.R.S.

Professor W. T. Thiselton Dyer, M.A., B.Sc.

Professor Flower, F.R.S.

Professor Michael Foster, M.D., F.R.S.

Colonel Lane Fox, President of the Anthropological Institute.

Mr. A. H. Garrod, M.A.

Mr. A. C. L. G. Günther, M.A., M.D., F.R.S.

The Hon. Alan Herbert.

Dr. J. D. Hooker, C.B., President of the Royal Society.

Professor T. H. Huxley, LL.D., F.R.S.

Professor E. Ray Lankester, M.A., F.R.S.

Mr. W. K. Parker, F.R.S.

Mr. G. W. Royston-Pigott, M.A., M.D., F.R.S.

Professor W. Rutherford, M.D.

Professor J. S. Burdon Sanderson, M.D., F.R.S.

Mr. H. C. Sorby, F.R.S., President of the Royal Microscopical Society.

Mr. F. H. Wenham.

fect that the viscosity and conductivity begin sensibly to diminish, even when the stratum of the medium experimented on is very thin.

But the most remarkable phenomenon hitherto observed in an empty space is that discovered by Mr. Crookes. A light body is delicately suspended in an exhausted vessel, and the radiation from the sun, or any other source of light or heat, is allowed to fall on it. The body is apparently repelled and moves away from the side on which the radiation falls.

This action is the more energetic the greater the perfection of the vacuum. When the pressure amounts to a millimetre or two the repulsion becomes very feeble, and at greater pressures an apparent attraction takes place, which, however, cannot be compared either in regularity or in intensity to the repulsion in a good vacuum.

From these instances we may see what important scientific discoveries may be looked for in consequence of improvements in the methods of obtaining a vacuum.

J. CLERK MAXWELL.

ACOUSTICAL INSTRUMENTS.

SOUND, from a physical point of view, may be defined as vibration appreciable to the ear. It appears, at its lower limit, to be continuous with vibration as detectable by common tactile sensation; hence its exact musical commencement is rather indefinite. It is usually given at thirty-two single or sixteen double vibrations per second. Apparatus for the demonstration of this fact will be noted farther on. Its higher limit is even more variable, owing to physiological differences between different ears; but 73,000 single or 36,500 double vibrations per second probably represent the highest note ever heard. Two organ pipes are exhibited, the individual sound of which is, for this reason, inaudible, but whose resultant tone is within the limits of hearing.

The line of demarcation between mere noise and musical sound seems similarly vague. Dr. Haughton has ingeniously shown that the rattling of vehicles over equal-sized stones becomes musical at a definite velocity; from the confused rattle of a railway train in a tunnel the practised ear can disentangle and, as it were, mentally sift out grand organ-harmonies; and a falling plank in the Crystal Palace gives musical notes by periodic re-percussion at equal intervals. On the other side, castanets, tomtoms, side-drums, triangles, cymbals, all instruments of music proper, only give noise similar to the guns added in Russia to Italian music, or the hundred anvils "played on" at the Boston Celebration. Even

Beethoven, in his grandest symphony, sounds every note of the scale at once with musical effect.

The present remarks are mainly concerned with instrumental appliances which minister to sound. The physical aspect of acoustics has been lucidly laid down in the introductory notice. To bridge over the gap between this science and the art of music slightly more extended treatment is needed; for instance, besides—

1.—Its modes of production.

2.— „ „ propagation.

3.— „ „ „ determination and measurement.

4.—An important consideration must be the history and ethnological variation of musical sound; nor can we omit (5) the various schemes of temperament and tuning, or the effects of heat on sounding bodies. Lastly—

6.—Special applications to music must be included in the list.

1.—The modes of production may best be considered under definite types, such as the following:—

Springs or rods.—Jew's-harp, "nail-fiddle," musical-box, tuning-fork, clock-gongs of wire, Wheatstone's resonating-tube.

Bells.—Spherical or irregular in shape, musical glasses.

Plates.—Steel, glass, stone, and wood, harmonicons, gongs, and Burmese bells, Indian instruments.

Strings.—Plucked, hammered, bowed, excited by wind, straight strings, simple or loaded, coiled spiral strings. Sustaining the sound of rods or strings by means of electricity, wind, or vibrating percussion.

Membranes.—Kettle-drums, &c.

Pipes.—Organ-pipes, wood, metal, reed.

Reeds.—Free, beating, compounded with strings or springs.

Musical flames.—Pyrophone.

2.—Modes of propagation may be studied, as—

Air.—Speaking-tubes, speaking trumpets, bells of wind instruments, velocity experiments, reinforcement-consonance in resonators, consonant vessels, as in Indian instruments and in Greek theatres.

Metal.—Wires, destruction of echo by interference.

Wood.—Telephone.

3.—The determination and measurement of sound may be accomplished by Savart's wheel, Sirens, Optical and Graphical methods, by Beats and Interferences.

4.—Its history and ethnology from ancient instruments and their reproduction, Egyptian pipes, hydraulic organs, Oriental and national instruments.

5.—Temperaments, &c. Perronet Thompson's inventions, Ellis's duodenes, Bosanquet's harmonium. Effects of Heat and Electricity.

6.—Special applications to music. Discoveries as to timbre or quality.

Physiological Aspect of Acoustics.

The audibility of acute sounds has been noticed above. Very elaborate apparatus is exhibited for determining the lower limit of musical character. Professor Helmholtz's experiments being made with a thin string, loaded with a copper coin, offered slight power of consonance or reinforcement, and the tone consequently soon faded out. In Messrs. Elliot's instrument, and in the four-string double-bass shown, better conditions of sympathetic vibration being afforded, and a larger mass of air being set in vibration, notes considerably lower in the scale were produced with musical character.

The perception of distinction, harmony, discord, and of melodious succession, appear to be in great measure due to acquirement, aided by natural sensitiveness of ear in the learner.

1. *Modes of production* are almost innumerable, if every variety be included.

Among the class of springs or rods the nail-fiddle seems the simplest. A circle of metal vibrators, each of which speaks to a certain note, is here touched by a bow, or even plucked by the finger. In the musical-box these vibrators are arranged in a long comb, being weighted on their underside and plucked by steel pins inserted into a rotating barrel kept in motion by clockwork and regulated by a fly. In the Jew's-harp the controlling power over the note is the volume of air in the cavity of the mouth, the lax "reed" or spring of the instrument being capable of responding to very different rapidities of vibration.

In tuning-forks, the necessity for firmly fixing the base of the rod or spring is obviated by attaching it to a second similar rod or spring, which vibrates in opposition, and keeps the whole mass in equilibrium. An instrument with single springs struck by hammers, and furnished with a key-board, is made by Messrs. Cramer and Co.

The wire gongs of American and other clocks are coiled into a flat spiral, attached to a heavy mass of metal at the outer end, and firmly screwed to the wood of the case; being struck by a hammer close to the fixed end, they produce very profound complex notes, much resembling those of a large church-bell.

Plates are illustrated by various instruments commonly called harmonicons, which may be made of wood, glass, steel, or even of compact stone. Many Oriental instruments are formed out of the first material, usually the outer silicious layer of the bamboo, and are remarkable for the presence of resonators reinforcing the note, which will be adverted to farther on. The amount of tone is astonishingly large and pure. Such an instrument, under the name of the "Xylophone," has recently been produced at many London concerts. Another, made of crystalline slate in bars, termed the "rock harmonicon," was exhibited a few years back. Mozart writes for a like instrument, probably made of steel, in his *Flauto Magico*, where it is supposed to imitate the sounds of the

sistrum, with which Papageno is entrusted. A remarkable instance of a large vibrating plate of metal is the so-called Chinese "bell" which is exhibited.

Bells proper are usually in the form of vessels either of hemispherical shape, as in clock-bells, or of a very complex outline, as in church and house-bells.

The musical-glasses, formerly in great repute, and recently revived, were a collection of glass vessels selected so as to form an approximate scale, and further tuned by pouring in water. Their note was excited by rubbing the free edge, either with the moistened finger, or with a wetted cloth. An ingenious modification of this arrangement is shown, wherein the bells are fixed to a rotating spindle, and touched while in rotation with a wetted excitor. The sounds thus obtained are continuous, and of peculiarly luscious, though cloying quality.

Strings embrace too many varieties for full discussion. The chief novelties exhibited are the flattened spiral strings described farther on, and the heavily covered string attached to a double bass, from which the sixteen-foot C can be produced without unwieldly increase of length.

The use of strings formed of an open coil has been before attempted, but without success, the coil being unable to withstand the necessary strain. This difficulty has been overcome by Mr. Baillie Hamilton, who has invented a process of rolling and tempering steel wire into a form such that the coil has enormous power of resistance to any strain that can be applied to a pianoforte string. Moreover, as the strain on every coil is chiefly lateral, the tension is that of a spring, and is not greatly affected by the causes which derange the pitch of ordinary strings. It is needless to point out the advantage of gaining more than the length of a grand pianoforte string in the space occupied by that of a small upright instrument.

Pipes and reeds present the same difficulty; the former, however, in their various forms, are shown; and the latter, as "free reeds," form the foundation of the "seraphine," harmonium, and American organ principle. Their "beating" modifications are to be seen in the organ, and in several orchestral instruments, such as the clarionet.

Membranes are chiefly met with in the form of drums, of which three varieties—the side drum, the bass drum, and kettle-drum—are in use. The first speaks a high, but undefined, note, the penetrating power of which is enhanced by the "snare," a loop of catgut stretched tightly across the lower membrane. The bass drum gives a similarly undefined, but extremely low, note. Both act chiefly in marking time and accent. The kettle-drum used in orchestras is a more strictly musical instrument than the two former. It gives a definite note of 8 or 16 foot tone. Two tuned to the tonic and dominant of the scale, or exceptionally to some other interval, are commonly employed, but a larger number is occasionally used with effect. Berlioz proposed to extend their employment, and in one of his works, the "Requiem," writes for a chromatic octave of twelve, tuned in semitones.

Modes of propagation in Air were studied by a French Commission in 1822. The observers were divided into two groups, placed respectively at Mont Lhéry and at Villejuif, and twelve alternate cannon shots were fired from each station. By measuring the interval between the appearance of the flash and the arrival of the sound, the rapidity of the latter was fixed, for 16° C., at 340·9 metres per second.

In Water, Colladon and Sturm made excellent observations on the Lake of Geneva. The sound was produced by the stroke of a hammer on a submerged bell, some gunpowder being at the same instant ignited. It was received by a kind of speaking trumpet, shown in the Exhibition, the bell being covered by a sheet of metal. The distance between the two stations, 13,487

metres, was traversed in 9·25 seconds, giving 1,435 metres per second as the velocity in water at 8° C.

In an Iron Pipe it was found by Biot to be 3,250 metres per second.

In Wood its transmission was ingeniously demonstrated by Wheatstone. His telephone consisted of long rods of light pine affixed in a lower room to various instruments. On a resonant body being attached to the upper end of the rods in an upper chamber, not only the pitch, but even the quality, of the various tones was distinctly reproduced.

The transmitting power of wood is daily used in the stethoscope for medical purposes.

Under this heading may be named the reinforcement produced by bells, or trumpet-like expansions seen at the lower end of many instruments; by the speaking trumpet on the voice; the effects of consonance in soundboards; in the bamboo harmonicon already named; and in the hollow vessels said to have been used in Greek theatres to increase the resonance of the actor's voice. In the measured and monotonic recitation of Greek tragedy, no doubt the result may have been favourable; though in the inflected diversities of modern speaking it would have had rather an opposite effect. The importance of consonance in securing greater audibility can, however, be traced in the practice of intoning as used in our large cathedrals.

The Bamboo Harmonicon, termed a *Marimba*, or *Balafo*, is furnished with a dried calabash or gourd beneath each resonating plate. A small hole is pierced into the cavity of the gourd and turned upwards towards the under surface of the plate. Around this hole is cemented a smaller gourd, with the two extremities removed, so as to form a cornet or receiver, evidently intended to direct a larger number of vibrations into the consonant cavity.

The determination and measurement of musical sound has, from the earliest times, been studied with success. Indeed, in the

monochord of Pythagoras we have an early machine which still remains of value. The "Pythagorean comma" is in frequent reference to this day, and his division of the string, followed by Euclid in the "Sectio Canonis," laid a foundation to the mathematical theory of music.

The Organ, whether in the hydraulic or pneumatic form, is the only other instrument involving scientific and mechanical construction which dates back to classical times. In the Hydraulic Organ, the principle of which is exhibited, fluid pressure was used to compress the air.

Whilst the monochord has, from the earliest times, illustrated the laws of strings, pipes have had no corresponding representative among scientific apparatus.

The organ itself, however, is essentially a great collection of apparatus whereby the tones of other instruments are imitated. We can easily recognise the characteristics of flute, trumpet, horn, voice, or string. Thus, while analysis of tone is modern, the artificial composition of tone has long been practised in organ pipes, and may still be advantageously studied in them; indeed, the mixture stops, known as "cornets" in old organs, were really an instinctive anticipation of Helmholtz's discoveries as to quality or timbre.

The materials of a pipe are either wood or metal, according to the form desired—wood being clearly suited for rectangular pipes, and metal for those of rounded or conical outlines; the material being selected more for the sake of solidity than for its influence upon tone.

Pipes fall into one of two great classes—flue and reed pipes—according to the mode in which the column of air is excited.

In flue-pipes the exciting cause is a sheet of wind passing over a mouth, exemplified in the case of a common whistle, which is, in fact, the representative of all flue-pipes.

Pipes, like whistles, form three groups, according as they are stopped at the end, half stopped, or entirely open. Each of

these groups has distinct characteristics. The stopped pipes have generally a soft and massive tone; the half stopped one, sweet and piercing; those entirely open, allowing a freer action of harmonics and setting more air in motion, give the more strident, although massive, effect peculiar to open diapasons.

These three groups are again subject to endless modifications of tone by the proportions of pipes; the diameter affecting those that are cylindrical, and the depth, from front to back, those that are rectangular. Moreover, the size of the sheet of wind at the mouth, the force of the blast, and its direction, can be made to evoke any peculiarity which the proportions of the pipe afford, and to give prominence to a certain set of harmonics, or to allow a relative succession of harmonics and fundamental, as in the case of the "Viol di gamba" pipe.

Reed-pipes, on the other hand, have their representative in the trumpet, where the vibration of the human lip, through which the wind passes into the tube, are the exciting cause. On examining a reed-pipe it will be seen how the "thrilling" lip is replaced by a metal tongue known as a "beating" reed.

Considering that any form of open or "shaded" tube can be applied to the reed in an organ, the great opportunity of varying tone, as compared with the trumpet, is evident, even if the reed were always the same; for, according to the proportions of the tube, and the gradual or rapid divergence of the cone, it is possible to give predominance either to the fundamental, or to a set of harmonics, or even to particular harmonics alone. But the reed can also be varied either as regards its pliancy, or its curve, or its freedom of motion.

In organs the reed employed is almost always a "beating reed," *i.e.*, the tongue cannot pass through the slit over which it is set, but strikes against it.

In free reeds the tongue can pass through without striking. Free reeds were introduced into Europe from China by Kratzenstein, and brought to perfection under Sir Charles Wheatstone.

They are used as the vibrators in harmoniums, and similar wind instruments. Their great recommendation is their cheapness and portability; since a note can be thus obtained without the conjunction of any sympathetic body or tube. They have, of course, the necessary defect of being unsympathetic and feeble in comparison with the organ. These defects are modified by the use of channels in harmoniums, by suction in the American organ, and by the use of shields and coverings for deadening and softening the sound.

Besides beating and free reeds, fresh combinations have recently been effected. The gradual development of a new condition of reed-power is illustrated by a collection of apparatus exhibited, tracing its history from the earliest Æolian types.

The simplest of these are found even among savages, who plant their spears in the ground and lie listening to the Æolian sounds.

A bow or a harp string was next found to have the same effect, and thus various forms of the Æolian harp are recorded in history.

Then came the more modern form claimed by Kircher, but more properly attributed to an Englishman named Pope. Then Schnell's anemochord, and other devices, the particulars of which are not recovered, making use of wind to set musical strings in vibration more or less sustained. Then we come to a peculiar arrangement of varnished ribbon or flat wire within a double organ-pipe, introduced by Professor Robison for evoking Æolian tones. Then a device for acting on one portion of the string only, as by Green and Wheatstone. The next change was in the adoption of a free reed tied by a silken thread to pianoforte wire, as in the instrument devised by Pope; then a reversion to the string alone, with one portion flattened and spread out to the whole force of the wind and preventing the lateral sway, as designed by Julyan; then the flattened portion replaced by a reed-tongue, with an attached wire in prolongation of length, as in Farmer's invention; then the reed-tongue separated from the prolonged string, and connected by a pin, as by Farmer and Hamil-

ton. Then come a series of experiments by Hamilton in conjunction with Hermann Smith, in which the reed tone is regarded apart from the string, and produced as an organ note, the string's functions analysed, and the string replaced by other bodies linked to the reed, and reacting upon it, and the mode of transmission to solid bodies investigated and illustrated. The discovery that reeds can obtain a sympathetic resonance from solid bodies leads to a new field of experiment. Reverting to experience, it is evident that besides the familiar instances of violin and organ-pipe, there exists in solid bodies the same power of strengthening and reacting upon a source of vibration.

We often hear organ-tones accidentally imitated in a large building. Thus the dragging of a bench across a marble floor will awake a grand violone sound; the shifting of a chair often gives rise to a clear trumpet tone; and sometimes the shivering of a great door as it slowly closes by its own weight rivals the note of the deepest pedal pipes. Such sounds cannot at once be discriminated from organ notes, but their want of continuity and of steady pitch robs them of all elements of grandeur, and reduces them to the level of noises.

In the large collection of apparatus contributed by Mr. Baillie Hamilton, we can estimate the chances of recovering to our use these sources of sound, necessarily ranking among their number the Æolian sounds, and sounds which have been often heard and enjoyed in nature, but which have not as yet been harmonised or controlled.

In the revival of mechanical methods, as applied to the determination of sound, which has taken place within the last century, an early instrument for computing vibrations continues to be of service, namely, Savart's toothed wheel; the teeth of which, rotating with a measurable velocity, are made to impinge on a resonant body, and the pitch of the note produced is compared with a standard.

But the tension and division of strings were also early utilised

in Longman and Broderip's Tuning Machine, which is exhibited, and which does not materially differ from the contrivances of Pythagoras.

Perronet Thompson followed the same system, in adjusting the so-called quarter-tones of his Enharmonic Organ. He used a monochord strung with steel wire, the adjustable weight rising regularly to 250 lbs.

Of late the Siren, in one or other of its forms, has been principally employed. A rotating disc, with oblique holes, is brought into close contact with a similar fixed disc, the obliquity of whose holes lies in the opposite direction; rotation is thus produced by the current of air, and a musical note by the alternate passage and obstruction of the stream; while a screw-counter registers the rapidity of rotation for a given pitch.

It is worthy of comment that the two mechanical principles thus laid down, have both been found ancillary to the measurement of the far more rapid vibrations of light; the toothed wheel in M. Fizeau's, and the siren in M. Foucault's experiments, recently repeated by M. Cornu with increased accuracy and elaboration.

Other modes of measurement are the Optical and the Graphical, severally connected with the apparatus of M. Lissajous, and the Vibration-Microscope of Helmholtz; with the curvetracers of Mr. Donkin and Mr. Tisley, and the Phonautograph. In the two former cases the figures obtained serve also to illustrate the phenomena of circular and elliptical polarization.

Lastly, the method of Beats and Interferences affords the best practical method of measurement for the purposes of tuning and comparison. These have of late been fully discussed in the great work of Helmholtz.

History and Ethnology.

It is of the highest moment here, as in other branches of science, to consider developments, now common and familiar, in the light of their history and distribution. It has been found practicable,

through the kind co-operation of Mr. W. Chappell, to present for exhibition a series of ancient Egyptian pipes, reproduced in *fac-simile* from those found in Egyptian tombs, preserved in the British Museum and Continental collections, with reeds complete, and to give a fair approximation to the scale on which they must have been played.

The applications of acoustical theory to music proper can only be very partially treated in a scientific exhibition. But the great discoveries of Helmholtz as to quality or timbre cannot be omitted. Apparatus for the illustration of the effect of "overtones" will be shown; as will be also several systems of true intonation as opposed to equal temperament. The chief defect of most of the former is the great complication of the key-boards. This is, however, ingeniously overcome in the Harmonium of Mr. Ellis, constructed according to the plan proposed in his paper on Duodenes, read before the Royal Society. In this instrument the usual twelve keys to the octave are retained, and the various notes are introduced by means of stops opening different combinations. Apparatus for illustrating the effect of heat and electricity on vibrating bodies is also exhibited.

The whole subject may be appropriately summed up in the following propositions:—

1. The respective influence of scientific apparatus on the art of music, and *vice versâ*.

At the very outset we meet with the monochord of Pythagoras, a machine which at once yielded immense practical results to music. We then enter into a long period during which instrumental appliances grew, but without design, and without theory. The discoveries of new or improved instruments were purely technical, often fortuitous; although every new member added was a piece of mechanism open to scientific analysis.

During the last century a return has been made to apparatus essentially scientific, for the explanation of what had been musically invented, and soon after we find,

2. The reciprocal influence of instruments on apparatus—no better instance of which can be found than the discovery of Tartini's "Terzo Suono," or third sound; originally taught by the great violinist to his pupils as a means of accurate tuning, but involving a new and important acoustical principle.

3. In many cases instruments of music actually stand in the place of apparatus. Strictly considered, a musical note is of itself a mathematical fact; quite independent of its power of exciting emotion and pleasure by its artistic production. On the other hand, tuning and intonation, originally left entirely to the accurate and cultivated ear of a skilled performer, have become a branch of science, with definite laws and practical rules; insomuch that the instinctive departures from a fixed tuning, which the older violinists made by a kind of instinct, are now explained, and even the disposition of various instruments with differing qualities in an orchestra is shown to be correct, or the contrary, according as the harmonics of each peculiar tone are consonant or dissonant.