OBITUARY NOTICES

OF

FELLOWS DECEASED.

PART i.

RUDOLF LEUCKART. 1822–1898.

CARL GEORG FRIEDRICH RUDOLF LEUCKART was born in the ancient university town of Helmstedt, on the 7th October, 1822, and died at Leipzig in his 76th year on February 6, 1898. He was elected a Foreign Member of the Royal Society in 1877. Leuckart was the nephew of a celebrated but less distinguished zoologist, Frederick Sigismund Leuckart, who does not appear to have had any share in directing the tastes of his younger relative.

In 1842 young Leuckart became a student of medicine in Göttingen, and was profoundly influenced by the teaching and friendship of Rudolf Wagner, who was professor of Physiology and Anatomy—the combination of these two subjects in one chair being then usual. Leuckart's dissertation for the degree of Doctor of Medicine was entitled "De monstris eorumque causis et ortu."

In 1852 Leuckart, having previously started as *privat-docent* in Göttingen, was called by the University of Giessen to the Chair of Zoology. Here he laid the foundations of his life's work and reputation in a series of most valuable and light-giving experimental researches on the natural history of parasitic worms. This subject remained his favourite throughout his career, but he was active in almost every department of morphology, and published valuable memoirs on some member of almost every class of the animal kingdom.

In 1869 Leuckart left Giessen in order to succeed Poppig as Professor in Leipzig, where he was soon provided with a new institute and a new museum. Students from all parts of Germany, from Russia, Great Britain, and the United States, came to pursue researches in his laboratory, especially researches upon parasitic worms. At the fiftieth

anniversary of his entry on the professorial career, he was made a Privy Councillor by the King of Saxony and Councillor of the city of Leipzig. On the same occasion his former pupils presented him with a "Festschrift," which is remarkable for the number and varied nationalities of the contributors. The volume in question contains a complete list of Leuckart's published memoirs and separate works. In 1873 he was Rector Magnificus of the university.

Leuckart was characterised by good-heartedness and ceaseless industry and enthusiasm in zoological investigation. He inspired warm regard in his pupils, whom he watched over with kindly and unflagging interest, not only whilst they were working with him but throughout their subsequent careers.

The more important only of Leuckart's long series of contributions to the literature of Comparative Anatomy and Zoology can be here referred to. Undoubtedly the most remarkable of his publications was among the earliest. It is a little book called 'Die Morphologie und Verwandtschaftsverhältnisse niederer Thiere,' printed at Brunswick in 1848. The power and originality of the author were clearly shown by this pamphlet. He boldly attacked and demolished the Cuvierian sub-kingdom of Radiata by separating and characterising the Cœlentera (or Cœlenterata as he in conjunction with Frey had termed them) as distinct from the Echinoderma. The conceptions which have since ripened into the doctrine of the archenteron and the cœlom are traceable to Leuckart's work, though important modifications in some respects have arisen with the progress of knowledge.

Leuckart originally stated, and repeated in 1869, that the cavity of the Cœlentera was "morphologically equivalent to the body-cavity (Leibes-höhle) of other animals." Haeckel in his "Kalkschwämme," vol. 1, p. 464, denied this, and declared that the cavity of Cœlentera is homologous with the digestive cavity of other animals, whilst their body-cavity has a totally independent origin. It is now generally held, as a result of the embryological researches of Kowalewsky, Balfour, and other English embryologists, that Leuckart's view was the more nearly correct, since the cavity of the Cœlentera is an "archenteron," which by constriction becomes divided in the higher animals into the permanent gut or "metenteron" and the "cœlom" or perigonadial and excretory cavity.

Soon after this publication Leuckart wrote the article "Zeugung," for his teacher Wagner's 'Handwörterbuch der Physiologie.' It is remarkable for philosophic grasp and wide range of treatment. In 1851 he produced a celebrated memoir "On the Polymorphism of the Siphonophora," a subject which about the same time engaged the attention of Huxley in this country. In 1853, under the title "Zoologische Untersuchungen," he published a series of observations on Siphonophora, Salpæ, Heteropoda, Cephalopoda, Crustacea, Insecta,

and Elasmobranch fishes. His volume 'On the Structure and Physiology of the Honey-bee,' produced about the same time, is the best treatise on the subject, and has been invaluable to scientific bee-masters.

One of Leuckart's most definite and striking discoveries was his demonstration by a study of their embryology that the worm-like parasites known as Linguatulidæ (Pentastoma) found in the body-cavity of serpents and other Vertebrata are degenerate Arthropoda, probably related to the Arachnida. His memoir on the anatomy and reproduction of those remarkable Diptera, the Pupipara, is a valuable contribution to the knowledge of insect morphology. His discoveries in relation to parasitic worms are numerous and of great importance. They are for the most part epitomised and incorporated with existing knowledge in his treatise, 'Die menschlichen Parasiten,' two volumes, of which the first edition appeared in 1863 and the last in 1876. Of this work there is an English translation.

He demonstrated the true nature and history of the remarkable nematoid worms, Attractonema and Sphærularia. He published in 1860 a separate work on *Trichina spiralis*, discovered originally by Sir James Paget when a student in the dissecting room of Bartholomew's Hospital, and named by Sir Richard Owen. Leuckart gave a complete history and anatomy of Trichina in its various phases of growth, and assisted by his work in checking the spread of trichinosis. One of his last discoveries was that of the intermediate host of the liver fluke, which he showed to be the small water-snail known as *Lymnæus periger*. In this discovery he was anticipated by a few weeks by Mr. Thomas, of Oxford, now Professor in Christchurch, New Zealand, who independently made the same discovery as the result of a long series of experiments, and published it in this country before Leuckart published his results.

Amongst other distinguished pupils of Leuckart is Elias Mecznikow —the founder of the theory of phagocytosis. Mecznikow discovered in Leuckart's laboratory the extraordinary life-history of the nematoid *Ascaris nigrovenosa* which has alternating complete sexual generations, the one parasitic in the lungs of the frog and the other living in damp earth.

Leuckart has the merit of being, if not the first, yet one of the very first to apply the method of "embedding" with a view to section cutting to small soft-bodied Invertebrata. The method itself was first devised by Samuel Stricker, of Vienna, who invented it in order to facilitate his study of the embryology of the frog. The simple form of embedding in wax or paraffin, which was used by these pioneers (about the year 1870), has long since been developed into the modern methods of impregnation with paraffin and the cutting of ribbons of sections by nicely adjusted machines.

Apart from all his other activities and constant hearty encouragement of his pupils and assistants, Leuckart for a long series of years rendered a great service to the zoological world by his admirable annual 'Bericht' or critical report on the progress of knowledge with regard to the anatomy and life-history of Invertebrata. Though the reports were often a couple of years later than the date of the memoirs recorded and epitomised, yet they were always looked for and read with great interest, on account both of the faculty which Leuckart had of bringing to light little-known and out-of-the-way publications of real value, and for the critical judgment and knowledge which he possessed and made use of so as to give significance to the observations of other workers which might otherwise have passed into oblivion. Rudolf Leuckart was a sturdy honest worker of first-rate ability and of wide sympathy and grasp of his subject. He rendered services of the highest value to the science to which he devoted his life, and his name will ever be held in veneration by zoologists and comparative anatomists.

It is worth while, perhaps, to draw attention—as a last word—to the fact that, more than is the case with other zoologists of distinction, Leuckart directed his work very frequently towards results of practical or economic utility—as, for instance, in the case of so many of his researches on parasitic worms and of his treatise on the honey-bee.

E. R. L.

Sir HENRY BARKLY. 1815–1898.

Sir Henry Barkly, born 1815, was the son of Aeneas Barkly, of Monteagle, Ross-shire, a West India merchant, who ruined by the Parliamentary legislation of 1838, left his family, on his death, in a financially embarrassed position. This led to young Barkly's going out to Demerara, for the purpose of improving his property. On this occasion he made a journey through British and Dutch Guiana, following the track of Sir Robert Schomburgk, and laying in stores of useful information on the resources of the colonies, which were the foundations of his love of science and of his future career as a public servant. On his return to England he, in 1845, entered Parliament as a Liberal Conservative for the borough of Leominster, and as a supporter of Sir R. Peel's Free Trade policy.

The sugar question was then, as now, a burning one, and Mr. Barkly at once made his mark in Parliament by his able speeches, displaying his profound knowledge of the subject. This led to his appointment by Earl Grey as Governor and Commander-in-Chief of British Guiana. His success as administrator of the affairs of that depressed colony secured his promotion, in 1853, to the Governorship of Jamaica, and successively to those of Victoria in 1856, Mauritius in 1863, and South Africa in 1871, to which was added the post of High Commissioner for settling the affairs of the eastern frontier of the latter colony.

In none of these colonies was his task a light one. In Jamaica he was confronted with grave financial problems, the successful solution of which demanded all his experience of the West Indies, his tact and his judgment. In Victoria, which was in the throes of its first trial of a responsible Government, matters were approaching a dead-lock when by his skill as an administrator and the charm of his manner, he reconciled all conflicting interests, and in less than a year restored complete harmony. The riots in the Ballarat Goldfields, then at the height of their prosperity, he quelled, after a tour of inspection, by inducing the legislature to substitute an export duty on gold for the monthly licences to search. In Mauritius he found the railway question beset with difficulties, which were no sooner adjusted than that outbreak of malarial fever, which for its virulence has become historic, commenced its decimation of the inhabitants, upwards of 30,000 of whom perished in Port Louis alone. The supply of quinine was exhausted at once and the last ounce has been reported to have fetched the perhaps fabulous, but credible, sum of £30. Steamers

had to be sent to India and the Cape for medical stores by the Governor, who, himself acutely sensitive to human suffering, laboured day and night in establishing local hospitals and appliances for the relief of the sick, and in restoring confidence to the panic-stricken people. The pestilence was followed by a hurricane of exceptional violence, which wrecked the houses and plantations over a great part of the island.

In the Cape Colony Sir Henry's first duty was the establishment of responsible government, in settling which he had to overcome the deep-rooted jealousy of the colonists of the Eastern and Western Provinces, who each claimed the right to the seat of Government. This settled, the discovery of diamonds led to a complication of the conflicting interests of the Boers, the native tribes, and the Orange and Transvaal Free States, which resulted in the adoption of the policy recommended by Sir Henry, namely to place the Vaal district under British protection, and to annex Griqualand West. The rising of Langalibalele and his people was the next source of trouble, though it affected Natal more than the Cape Colony. All these complications led to Sir Henry's turning his attention to a confederation of all the South African States and Colonies, towards which he worked with characteristic energy and prudence; but, though favourable signs of progress in the right direction were not wanting, the time had not come for its realization, and, to his bitter disappointment, Mr. Froude's mission shelved the whole subject. He returned to England in 1877, when he retired upon his well-earned pension.

During the whole period of Sir Henry's service, he not only actively promoted (and in some cases originated) every scientific movement in the colonies which he administered, but himself collected and observed largely, sending living plants and herbarium specimens to Kew, and fossils to the British Museum, with both which institutions he kept up a continuous correspondence. To him is greatly due the enrichment of the Botanical Gardens at Victoria, the appointment of Sir F. Mueller as Government Botanist, and the undertaking by the Governments of four of the Australian Colonies of the 'Flora Australiensis.' Aided by Lady Barkly, he explored the fern floras of Jamaica and of Mauritius and its dependencies, and he contributed a very valuable paper to our 'Transactions' on the peculiar vegetation of Round Island; and another on its fauna, to the Royal Society of Mauritius.

Sir H. Barkly was a man of varied accomplishments, tall and spare in person, retiring in disposition, and urbane in manner, the kindest of friends and most judicious of counsellors to young and old. The most harassing duties never disturbed his equanimity, and he was a true exponent of the motto he adopted "*per ardua surgo.*" He married, in 1840, Elizabeth Helen, daughter of Capt. J. T. Timins, of Hilfield, Herts, and secondly in 1860, Anne Maria, the only

daughter of Sir T. S. Pratt, K.C.B., who survives him. He was created K.C.B. in 1853, G.C.M.G. in 1874, and was elected F.R.S. in 1884. He died in London, October, 1898, in his 84th year, and was buried in Brompton Cemetery.

J. D. H.

GEORGE JAMES ALLMAN. 1812–1898.

George James Allman was born in Cork in the year 1812, and died on November 24, 1898, at the age of 86. His early years were spent in Belfast, and he was educated at the Academical Institution in that city. His original intention was to study for the bar, but developing an enthusiastic love for Natural History, he changed the course of his education and graduated in Arts and in Medicine at the University of Dublin in 1844.

Having already made his mark as a man of distinction in the scientific world, he was appointed to the Professorship of Botany in the University of Dublin, in succession to Dr. William Allman, and he held this post from the year of his graduation until 1856, when he was appointed Regius Professor of Natural History in the University of Edinburgh. He retained his Professorship at Edinburgh until 1870 when, in consequence of failing health, he resigned.

Two features marked his career as a teacher; his great skill in drawing animals and their organs upon the blackboard, and the encouragement he gave to his students to accompany him on his dredging expeditions on the Forth and to study the animals he obtained in their fresh living condition. One of his former pupils has informed me that Allman never made the mistake of attempting to crowd into his lectures too much information. He began with a brief recapitulation of the last lecture, and then coming to the new matter, spoke with deliberate eloquence, and using the blackboard with great skill made an impression upon his audience which it was difficult to forget.

After his resignation of the Professorship of Natural History at Edinburgh, Allman retired to Parkstone, in Dorsetshire, where he devoted the remaining years of his life to original work in zoology, and to the pursuit of his favourite pastime of horticulture.

The number of papers of original research published by Allman is considerable, including many important essays on botanical subjects, and on animals belonging to nearly all the large classes. Throughout they are distinguished by a very remarkable foresight in the appreciation of really important features, and by the artistic skill and accuracy

of his drawings and descriptions. The impression which Allman has made upon biological science is of two kinds, that of the specialist in the Hydrozoa and the phylactolæmatous Polyzoa, and that of the general biological philosopher.

Allman's great work on gymnoblastic Hydrozoa, which was published by the Ray Society in 1871-2, is without doubt the most important systematic work dealing with the group of Cœlenterata that has ever been produced. The excellence of the illustrations alone would almost justify us in placing this work in the first rank of zoological treatises. The soft and delicate bodies of these zoophytes are such that no method of preservation that is known to us can give to our museums anything but distorted and shrivelled cadavera of the living organisms, nor can the most eloquent description convey to the mind an accurate idea of their form and grace. This being the case, great confusion arises in naming and describing species unless there are some drawings that are absolutely trustworthy in existence, to which reference may be made. Allman's drawings of Hydrozoa and of the fresh-water Polyzoa have as a matter of fact become the "types" to which zoologists will refer for many years to come, and as such they are of extreme importance.

But the great monograph on the Hydrozoa was far more than an excellent illustrated statement of species, for it contained a most important and concise account of the anatomical structure of these animals based very largely upon his own researches.

The memoir on the structure of *Cordylophora lacustris*, which was published in the 'Philosophical Transactions' in 1863, may be regarded as the starting point of that work on Cœlenterates which will be particularly associated with his name. It was in this memoir that he clearly defined the two cellular layers of the Cœlenterate body-wall and gave to them the names "Ectoderm" and "Endoderm," which are now so familiar to all students of Biology. To Allman we are also indebted for many useful terms such as "Cœnosarc," "Trophosome," "Gonosome," and many others which have a more special application to Hydrozoan structure. Many of his papers and monographs are illustrated in the text by woodcuts, which show, in a diagrammatic form, his conception of the important features of structure and the homologies of the organs of one animal with those of others. Many zoologists have shown their appreciation of this method by copying into their text-books Allman's figures, and by constructing diagrams of the same general type to illustrate their own researches.

Of his writings that have a more general bearing, perhaps the most important theme was the method to be adopted for the construction and limitation of genera and species. Thirty-five years ago when Allman took up this matter, there was a great deal of very unsatisfactory work on systematic zoology in course of publication. New species and new genera were named in great numbers, many of which were based on

single specimens or fragments of specimens, insufficiently described and very imperfectly investigated. Although this kind of work still goes on, to Allman and two or three of his contemporaries the credit is due of having checked it. His studies in the group of Hydrozoa led him to the conviction that a species cannot be regarded as being satisfactorily defined until the whole of its life-history is known, and it may be observed that in his monograph he carefully states the characters of both the trophosome and gonosome stages of the species of Hydrozoa he investigated.

The general appreciation of Allman's investigations is shown by the honours he obtained. He was elected a fellow of the Royal Society in 1854, served on the Council of the Society from 1871-1873, and received its gold medal in 1873. He was President of the Linnean Society from 1874-1881, and President of the British Association for the Advancement of Science at the Sheffield meeting in 1879. He received the Brisbane gold medal of the Royal Society of Edinburgh in 1877, the Cunningham gold medal of the Royal Irish Academy in 1878, and the gold medal of the Linnean Society in 1896.

S. J. H.

Sir WILLIAM JENNER. 1815–1898.

Sir William Jenner, who died on December 11, 1898, was born at Chatham in 1815, and entered on his medical studies at University College, London, in the early years of the Institution, immediately after the opening of University College Hospital, obtaining his qualifications to practice in 1837. After holding an assistantship in the country, he entered on general practice near the Regent's Park, and in 1844 he took the degree of M.D. in the University of London. His attention had early been directed to the confusion then existing regarding the specific fevers, and he utilised his leisure time in their practical study at the London Fever Hospital. The results were published in 1849, as a minute differential description of a series of cases of typhus and typhoid fevers, so carefully observed, and thoroughly recorded, that his facts and close reasoning settled for ever the question of the non-identity of the two diseases.

The excellence of the work attracted attention, and the same year he was appointed Professor of Pathological Anatomy in University College, and Assistant Physician to the Hospital, becoming Physician in 1854, and soon afterwards he was placed in charge of a special department for diseases of the skin. In 1852 he became Physician to the Hospital for Sick Children, and in 1853 to the London Fever Hospital. He had thus abundant opportunities for the special study of many classes of disease, of which he made the fullest use. He combined clinical and pathological observation with ardent industry, and ever strove with brilliant success to obtain a clear insight into the relations between morbid processes and the symptoms by which they are manifested. His conclusions were carefully reasoned out and expressed in clearest and most convincing manner, and his published writings on Rickets, Inherited Syphilis, Diseases of the Skin, and, at a later date, on Diptheria, Emphysema, and Abdominal Tumours, are admirable examples of the application to medicine of a strict scientific method, with practical ends always in view.

In 1861, on the death of Dr. Baly, he was appointed Physician-in-Ordinary to the Queen, with the high responsibility of personal charge of Her Majesty and the Prince Consort, a post which entailed attendance on the latter during the fatal attack of typhoid fever in the following year. He continued to be the trusted adviser of the Queen until his retirement from practice in 1889. He was made a baronet in 1868, a K.C.B. after the severe illness of the Prince of Wales in 1871, and a G.C.B. on his retirement, receiving thus the

highest titular honours short of a peerage, to which a professional man could aspire.

Sir William Jenner very early acquired the absolute confidence of the members of his own profession, and the profound regard of all who came in contact with him. He had laid a solid foundation in consulting practice before his Court appointment brought him conspicuously before the general public, and he quickly attained one of the largest consulting practices achieved by any physician of the century. In 1862 he was appointed Professor of Medicine in University College, a post which the exigencies of private work compelled him to relinquish in 1867. His lectures were highly prized by his students for their unique practical quality, the outcome of his vast experience and close habitual observation. But it was in his bedside teaching and in the post mortem room that these characteristics found their most brilliant expression. His thoroughness and precision of observation, lucid exposition, and clear logical reasoning, impressed indelibly the facts of disease and the *rationale* of its treatment on the mind of the hearer, and elicited the admiration of an occasional chance auditor from outside the profession. He resigned his connection with the Fever Hospital on receiving his Court appointment, and with the Hospital for Sick Children about the same time, but continued his work at University College Hospital until 1878. In 1881 he was elected President of the College of Physicians, the highest post in the medical profession, and was re-elected annually for six years. During his term of office he took a leading part in several important proceedings, especially in the amalgamation of the examinations of the College with those of the College of Surgeons to confer the "Conjoint Diploma." It was under his influence that the movement for a "Teaching University" first took practical shape in proposals that were not destined to survive, but which largely excited the more enduring movement. He felt strongly the injustice to London students, and practical disadvantage, entailed by their inability to obtain an M.D. degree for knowledge and practical training equal or superior to that which secures it in the provinces and sister kingdoms, and urged strongly that a beginning should be made by the conjoined Colleges, but the opposition of the graduates of existing Universities was fatal to the proposal.

Sir William Jenner was elected a Fellow of the Royal Society in 1864, and few physicians have more distinctly justified the honour, both by the scientific character of their medical work, or by the professional eminence to which they have attained. He was a staunch friend, somewhat ready to take personal offence, but kind, warm-hearted, and just, never permitting personal feeling to interfere with his sense of what was right to the individual, or desirable for others.

W. R. G.

Rev. BARTHOLOMEW PRICE. 1818–1898.

The Rev. Bartholomew Price, D.D., was born in 1818, at Coln St. Denis, Gloucestershire, of which parish his father, the Rev. William Price, was rector. He entered the University of Oxford as scholar of Pembroke College, and graduated B.A. in Michaelmas Term, 1840, with a third class *in Literis Humanioribus*, and a first class in mathematics.

In 1842 he gained the University Mathematical Scholarship, and in 1844 he was elected Fellow of his College, in which he subsequently held the offices of Tutor, Mathematical Lecturer, and Bursar.

In 1853 he succeeded the Rev. G. L. Cooke, as Sedleian Professor of Natural Philosophy, and thus became a member of the University staff, then less numerous than at present, on which the other representatives of mathematics and natural science were Buckland, Baden Powell, Daubeny, Donkin, Ogle, and Walker.

Besides those who received instruction from him in his capacities of Professor and College Lecturer, a considerable number of private pupils obtained from him the more detailed tuition required in the higher branches of mathematics, so that for many years he took a large share of the teaching in these subjects in Oxford.

In this work he aimed at a high ideal, and by his energy, by his care in training those who sought his assistance, and by his power of inspiring others with enthusiasm in the acquisition of knowledge similar to that which determined his own efforts, he did much to raise the standard of mathematical attainment in the University.

To the last he took the keenest interest in the progress of the Mathematical School, and when the pressure of other duties compelled him to take a smaller share in the actual work of teaching, he had the satisfaction of seeing it carried on to a considerable extent by his pupils, many of whom had become professors or college lecturers.

In 1855, Professor Price became a member of the Hebdomadal Council, then only in the second year of its existence, and on each occasion that his six-years'-term of office expired, he was re-elected, so that he remained continuously until the summer of 1898 a member of the body by which all University legislation is initiated.

During these forty-three years the changes which have been introduced into all departments have been so great, that it would be impossible to form a correct idea of the condition of the University at the beginning of the period from any observations of what prevails now.

The change in the educational position may be taken as an instance of what has been accomplished in this period. Though the monopoly of classics and mathematics had been abolished two years before it commences, the two new directions of intellectual activity then opened to students had been followed by very few. At the present time, in addition to the two original roads to University honours, these distinctions can be reached through natural science, jurisprudence, modern history, theology, Oriental languages, English language and literature, and civil law, and the increase in the number of the names included in the class lists of the final examination for honours affords unmistakable evidence as to the effect produced by the extended facilities offered to students. This number was 175 in 1852, the last year in which classics and mathematics stood alone. In 1855 it fell to 144, probably from causes external to the University. In 1898 it had risen to 450, and to this should be added 42, on account of the women then admitted to the examinations.

In effecting all the changes to which reference has been made, Professor Price took a leading part, and his wise counsel, his sound judgment, and his influential support were always at the service of the workers in the cause of progress.

He was especially interested in promoting the study of natural science, and he strove earnestly, whenever it was possible, to secure the means of supplying efficient instruction in the different branches of this subject. He was one of the small but enthusiastic band of supporters of the then scarcely existent School, who saw the importance of uniting all the appliances for teaching science into a single institution, and who eventually succeeded in persuading the University to carry their plan into execution. Most of these pioneers have passed away, and comparatively few are now living who remember the fierce opposition they had to encounter before victory was secured, but the University museum stands as a memorial of their energy and devotion, and the group of laboratories now clustering round the original building opened in 1860, is evidence of the lasting success of the struggle, while it bears testimony to the efforts made during the last thirty-five years to improve the University as a place of scientific training.

All proposals for the extension of the museum were warmly supported by Professor Price, and it is not too much to say that they were indebted for their accomplishment, in no small degree, to his judicious advocacy in the Council and in Convocation.

But Professor Price's labours as a teacher, a legislator, and a reformer constitute by no means the whole of the services he rendered to the University, and to the cause of education; he took also a most active part in the administration of many of the most important departments. When, in 1868, the management of the estates and the

general supervision of the finances of the University were confided to a special Board—the Curators of the Chest—he was at once placed upon this Board, and so remained during the thirty years which elapsed before his death. He was also for many years a Curator of the Bodleian Library, a Delegate of the Museum, and a member of several other delegacies. In addition he discharged the duties of Examiner in Mathematics, either for Moderations or for the Final School, during seventeen years.

Nor is this all. In 1868 Professor Price undertook the onerous duties of the Secretary to the Delegates of the Press, and his skill in matters of finance, combined with his capacity for business, became in yet another direction of the greatest service to the University. During his tenure of this office, which lasted until 1884, the operations of the "Clarendon Press" became largely extended, and the series of text-books which made the name very widely known, as well as the numerous important works in all branches of literature and science which issued from this press, have done much towards the improvement of education and the advancement of knowledge.

When he resigned the office of Secretary he was elected to be a permanent member of the Delegacy, so that his connection with the Clarendon Press continued to the end of his life, and he never ceased to render valuable assistance in the management of this Institution.

After the creation, by the last University Commissioners in 1881, of Boards of Faculties to control the studies of the University, Professor Price was chosen to be chairman of the Board of Mathematics and Natural Science. The discharge of this new duty was not always unattended by difficulties, and it is a clear indication of the tact and judgment with which he conducted the business, as well as of the high esteem in which he was held by all those engaged in scientific pursuits in Oxford, that he was unanimously re-elected to this office every year until his death.

When the Mastership of Pembroke College became vacant by the death of Dr. E. Evans, and the Fellows failed to elect his successor, the Chancellor of the University, acting as Visitor of the College, appointed, in 1892, Professor Price to be the Head of the Society of which he had been a member throughout the whole period of his university career.

Considering the incessant demands upon his time and attention, arising from the very numerous duties which he had undertaken in the University, it could scarcely be expected that Professor Price would be able to find leisure for much original scientific work, and he only contributed two papers to the Ashmolean Society on the principles involved in mathematics, and one to the British Association on 'The influence of the Rotation of the Earth on the apparent Path of a heavy Particle.'

His reputation as a mathematician rests mainly upon his elaborate 'Treatise on Infinitesimal Calculus,' in four volumes, which in the second edition extends to 2663 octavo pages.

At the time that Professor Price was specially engaged in teaching he was impressed by the difficulty which an English student experienced in becoming acquainted with the progress which had been made, both in this country and on the Continent, in the developments and applications of the differential and integral calculus, and he set himself the heavy task of supplying a book which would assist to a great extent in removing this difficulty.

The work he contemplated and eventually produced was somewhat on the lines of Professor De Morgan's Treatise on the Differential and Integral Calculus, published under the auspices of the Society for the Diffusion of Useful Knowledge; but though this book, which had then been completed nearly ten years, and was becoming less easy to be obtained, suggested the scope of the new treatise, he endeavoured to improve upon it by introducing the more recent investigations and by arranging the matter in a manner more likely to be useful to a student.

The first volume on the Differential Calculus, with its applications to Geometry appeared in 1852, and was followed, after an interval of about two years, by the second volume on the Integral Calculus, the Calculus of Variations and Differential Equations. After, again, an interval of about two years, in 1856, the third volume was published treating of Statics and Dynamics of a Particle. The fourth volume on the Dynamics of Material Systems, did not appear until six years later, viz., in 1862.

Those who were studying mathematics, not only in Oxford but throughout the country during the decade covered by the publication of Professor Price's work, will remember with gratitude the wide field of knowledge that he opened up to them, and the stores of information that he placed at their disposal with such remarkable skill in arrangement and clearness in exposition. Even if exception might be taken to some details in the method adopted in treating the fundamental principles of mechanics, there could be no difference of opinion as to the usefulness of a work presenting such an important group of subjects from the point of view in which they were regarded by one well qualified to discuss their inherent difficulties, who had spared no pains in acquiring a knowledge of all that was most valuable in the writings of those who had preceded him.

Regarding this treatise as the text-book used by his pupils, and as representing his oral teaching—a circumstance to which reference is made in every volume—it affords the strongest evidence as to the high standard to which Professor Price strove to raise the Oxford school of mathematics. That it relieved a want really felt at the time of its

publication is evident from the fact that a second edition of the first two volumes was called for and partly supplied before the last volume issued from the press. It has now no doubt been superseded by more recent books—special treatises on subjects to which Professor Price devoted chapters or sections—but the second edition of the fourth volume, which was carefully revised and brought up to the time of publication, may still be very useful to a student; he will find in it an excellent account of the state at which the study of Rigid Dynamics had arrived in 1889.

Professor Price was elected into the Royal Society in 1852, and, besides assisting in various ways in carrying on the work of the Society as a member of committees, he served on the council for an aggregate period of eight years, during two of which he held the office of Vice-President. He was also for many years one of the representatives of the Society on the Board of Visitors of the Royal Observatory at Greenwich. He was, moreover, a Fellow of the Royal Astronomical Society, of the London Mathematical Society, and of the Physical Society of London, an Honorary Fellow of Queen's College, Oxford, and a Fellow of Winchester College.

Until the summer of 1898 Professor Price remained in the full discharge of the numerous duties which had accumulated upon him, but advancing years and signs of failing health induced him then to seek partial relief from work and anxiety by resigning his professorship and some of his other offices. There seemed at that time to be good reason to hope that rest would restore him to health, and that still for some years the University, which he had conspicuously served so long and so well, might continue to profit by his experience and his advice; but his strength rapidly gave way, and he died in Pembroke College on the 29th of December, 1898, in the 81st year of his age.

R. B. C.

HENRY ALLEYNE NICHOLSON. 1844–1899.

HENRY ALLEYNE NICHOLSON was born at Penrith in Cumberland on the 11th of September, 1844. His father, Dr. John Nicholson, was a Biblical and Oriental scholar of distinction. Nicholson was sent to Appleby Grammar School, and subsequently to the University of Göttingen, where it was his intention to study philology, though he soon abandoned this in favour of the Natural Sciences, and worked under the eminent zoologist, Keferstein. From Göttingen he passed to the University of Edinburgh, where he studied medicine from 1862 to 1867, graduating as Bachelor of Medicine and Master of Surgery in the latter year. He had already (in 1866) become a Bachelor of Science, and in the following year obtained his Doctor's degree in science. Shortly after this he took the degree of Doctor of Medicine at Edinburgh and that of Doctor of Philosophy at Göttingen.

In the year 1866 he was elected Baxter Scholar in the Natural Sciences at Edinburgh University, and in the following year sent in a thesis for graduation as Bachelor of Medicine. This was his well-known 'Essay on the Geology of Cumberland and Westmorland,' for which he was awarded a University Gold Medal; the essay was soon afterwards published, and dedicated to "his friend and teacher" Robert Harkness, then Professor of Geology in Queen's College, Cork.

In 1869, when he proceeded to the degree of Doctor of Medicine, Nicholson was awarded the Ettles Medical Scholarship, which is given annually to the most distinguished medical graduate of the year. In the same year he was appointed to a Lectureship in Natural History in the Extra-Academical School of Medicine, which is attached to the University of Edinburgh. In 1871 he visited Canada, and was offered the Professorship of Natural History in the University of Toronto, a post which he accepted and retained for three years. He was then elected, almost simultaneously, to the Professorship of Comparative Anatomy and Zoology in the Royal College of Science, Dublin, and to that of Biology in the Durham College of Science; he accepted the latter appointment, but very shortly after this (in 1875), he received from the Marquess of Ailsa the offer of the Chair of Natural History in the University of St. Andrews. This offer, which was unsolicited, for Nicholson was not a candidate either directly or indirectly, was accepted. In 1877 he was for the first time appointed Swiney Lecturer by the Trustees of the British Museum, and the four courses of lectures which he delivered, were greatly appreciated by his audiences. In the following year, when Sir Wyville Thomson, who occupied the Chair of

Natural History in the University of Edinburgh, was incapacitated by illness, Nicholson acted as his deputy, and conducted the work through the two succeeding sessions. In 1882 he was appointed to the Professorship of Natural History in the University of Aberdeen, and occupied the chair to the day of his death on January 19th of the present year (1899). Nicholson was elected Fellow of the Royal Society in 1897. He was also a Fellow of the Geological, Linnæan, and many other learned societies. In 1888 he was awarded the Lyell Medal of the Geological Society.*

Though Professor Nicholson's published writings give ample proofs of his acumen and industry, no account of his life would be complete which did not refer to the influence of his personality and to his powers of exposition. He possessed all the qualifications of a successful teacher. The success of his Swiney Lectures has already been mentioned, and he was equally successful in the lecture rooms and laboratories of the various Universities with which he was from time to time connected. Those who attended his lectures were impressed by his dignified manner, ease of delivery, and clearness of style, as well as by the excellence of the subject matter of his discourses. It is written of him that "He never had to keep order: discipline was the atmosphere of his lecture room." His lectures were illustrated by beautiful diagrams, which were his own work. The difficulties which he overcame will be appreciated when it is remembered that in these days of specialisation, when many large Universities require two or three teachers of one subject, each of whom devotes himself to the elucidation of one special branch of that subject, Nicholson undertook to teach Geology in addition to Zoology. Circumstances so moulded his life that it was his duty to teach Zoology, but it was the history of past times and of the now extinct beings which then dwelt on the earth which exercised the greatest fascination over him. It was his duty to teach Zoology, but he also taught Geology with so much success at Aberdeen, that, in a very few years after commencing his geological course, his class contained about eighty students. In connection with his geological course he was wont to take his students to some centre, such as Appleby, where he could give practical instruction out of doors. These excursions were evidently appreciated very highly, as well they might be, for Nicholson was perhaps at his best when wandering among his native fells, hammer in hand, but of this more anon.

The simplicity and clearness which marked his lectures are also characteristic of his educational works. He wrote several of these, treating of Geology as well as Zoology. Those which are best known are his 'Manual of Zoology,' which has reached the seventh edition, 'The Ancient Life-History of the Earth,' in which fossils are treated

* Many of the facts which are recorded above are taken from a notice which appeared in 'The Daily Free Press' (Aberdeen) for January 20, 1899.

to a large extent in chronological order, and the 'Manual of Palæontology,' of which the third edition, written in collaboration with Mr. R. Lydekker, has appeared in a greatly enlarged form in two volumes.

The original writings of the late Professor treated of a great variety of subjects, zoological, palæontological, and geological. Concerning existing organisms he wrote little though he reported upon the deep water fauna of Lake Ontario, and his report was published by the Legislature of Ontario; it is however by his geological writings and especially by those which treat of palæontology, that he has made his mark as an original investigator.

He wrote about 200 papers and memoirs, dealing with a great variety of subjects, both stratigraphical and palæontological; the most important were devoted to the study of some of the comparatively lowly organisms which once inhabited the earth, especially the Hydrozoa and Actinozoa. One of his earliest publications was a contribution to the study of the graptolites, 'A Monograph of the British Graptolitidæ' (1872), which was never completed: this work and the separate memoirs which Nicholson wrote, dealing with this group, will cause him to be ever associated with Barrande, Hall, and Lapworth as a pioneer in the study of a group of fossils of great importance. He not only contributed largely to our knowledge of the morphology and classification of the graptolites, but utilised them with great success as aids to stratigraphical research, and it is of interest to learn that in his later years he returned with enthusiasm to the study of these, his early favourites. From among Nicholson's many other writings, we may select for special mention his work on 'The Structure and Affinities of the Tabulate Corals of the Palæozoic Period' (1879), and the 'Monograph of the British Stromatoporoids,' published by the Palæontographical Society, which was commenced in 1885 and completed in 1892.

Professor Nicholson's stratigraphical work was chiefly done in our English Lakeland and the adjoining regions; in this work he utilised his palæontological knowledge with much success, and accordingly his papers on the district have far more than a local value. He no doubt made occasional mistakes—who has not?—but they are alluded to here for a particular reason. Far from being annoyed when others detected his errors, Nicholson was really grateful to those who corrected him.

It was during the prosecution of his researches among the rocks of Lakeland that the writer of this notice first met Nicholson, and since that first meeting, he has spent many happy weeks with him, wandering over the fells of that fascinating region. It was at these times that Nicholson's character was so perfectly revealed. Always eager for work, he let slip no opportunity of enlarging his knowledge of the district. Of his work we can make some estimate by what he has left behind him, but no one can calculate the inestimable benefits which his

friends and pupils reaped by contact with this loveable man. His hearty laugh was an indication of his joyous nature; he was joyous, not through absence of care, but because his honest and upright mind was so far removed from evil. But he could be angry, though anger was rare with him. Slow to believe that any among his acquaintances should be capable of meanness, if he was finally convinced that a mean action had been committed his anger was undisguised.

He has gone, leaving behind him a monument of work, but leaving also a wealth of tender feelings in the hearts of his friends. Science, like other branches of knowledge, counts among its devotees men of very different character. As examples to whom we would wish the attention of mankind to be directed, are those earnest students of nature in whom the love of knowledge and of humanity are combined with that true humility which is quickened by communion with Nature. The highest tribute that we can pay to him for whom we mourn, is to say that he was enrolled among the members of this goodly company.

J. E. M.

Rev. THOMAS HINCKS. 1818-1899.

The Rev. Thomas Hincks was born at Exeter, July 15, 1818, the son of the Rev. W. Hincks, Professor of Natural Philosophy at Manchester New College, York, afterwards Professor of Natural History in Queen's College, Cork, and in the University of Toronto, where he died in 1871. Thomas Hincks was nephew to the Rev. Edward Hincks, the well-known Egyptologist. He was educated at Belfast, and in the Manchester New College, from which he entered the Unitarian ministry. He was minister at Cork (1839), Dublin (1842), Warrington (1844), Exeter (1846), Sheffield (1852), and Leeds (1855). He married Elizabeth, daughter of Mr. John Allan, of Warrington, who, with two daughters, survives him. While minister at Cork, in 1840, he graduated B.A. in the London University. He was elected a Fellow of the Royal Society in 1872.

In Leeds Hincks succeeded, after a long interval, to the post once held by Dr. Priestley, and rendered memorable in the history of science by experiments preliminary to the discovery of oxygen. In his profession Hincks was active and highly respected. The old meeting house, in which Priestley taught, had been replaced by a modern chapel, to which Hincks had the satisfaction of adding schools and a congregational hall. He was prominent in educational and philanthropic work in Leeds until his breakdown in 1868. A year's leave of absence was tried in vain. In March, 1869, he was compelled to lay down his ministry, and though he lived for thirty years longer in activity and usefulness, he was unable to address any but the smallest gatherings, and these only at long intervals. "The tragedy of his life," says his widow, "was the loss of voice and the consequent enforced withdrawal from all public work." Mr. Hincks died at Clifton, where he had spent most of the years of his retirement, on January 25, 1899.

Mrs. Hincks gives the following particulars concerning her husband's work in natural history:—"I think my husband's love of natural history was hereditary. His father was a botanist, whose enthusiasm seemed to inspire all his children with a love of the study of nature. What caused Mr. Hincks to take up zoophytes as his special study I do not know. It might be that in youth he was closely associated with his life-long friend, Professor Allman. He was a persistent dredger during his holidays by the sea. Familiar as he was with very much of the British coast, his chief work was done on that of Devonshire, both north and south, and in the beautiful estuary of Salcombe.

Mr. Hincks was a most successful and laborious gardener. Indeed, no natural object, from the simplest wild flower to the passing cloud, failed to delight him."

His two books, the 'History of British Hydroid Zoophytes' (1868) and the 'History of British Marine Polyzoa' (1880), are well known to all students of marine zoology. They incorporate the best systematic knowledge of the age with respect to these large and difficult groups. Hincks was most careful and lucid in description, skilful in drawing, well read, diligent, and candid. Though description and systematic arrangement were his strong points, he was keen to appreciate the work of others in minute anatomy, embryology, and allied studies which he did not himself regularly pursue. During the preparation of his larger works he published many papers on special forms of Hydrozoa and Polyzoa, chiefly in the 'Annals and Magazine of Natural History.' Collected sets of these opuscula (1894) are to be found in public libraries. An index, with additions, was published in 1895. His collections are chiefly preserved in the British Museum of Natural History.

Mr. Hincks was a generous and disinterested friend. He had nothing of the selfishness of the baser sort of collectors, but would put a fellow student on the track of some natural history prize which he had just discovered. In every relation of life he was estimable. His amiable disposition, his lively conversation, his faithful services in his chosen profession as well as in that branch of natural history which, though at first a mere bye-pursuit, became in the end a serious part of his life-work, will never be forgotten by those who enjoyed his friendship.

L. C. M.

GUSTAV WIEDEMANN. 1826–1898.

Gustav Heinrich Wiedemann was born in Berlin in October, 1826. Before he was two years old, his father died, and he was scarcely fifteen when he lost his mother also. He was thus from an early age thrown much upon his own resources, but the care of friends secured for him a careful classical and scientific education. His inclination to the special study of physics, seems to have been largely due to the influence of Seebeck, who, for several years, was one of his teachers at the Cologne Gymnasium. From Cologne he proceeded, in 1844, to the University of Berlin, where he entered upon a serious course of study of mathematics, under Dirichlet and Joachimstal, and attended the chemical lectures of Heinrich Rose, and worked practically at chemistry in the private laboratory of Sonnenschein. Later he attended the lectures of Dove, Magnus, Mitscherlich and others. When he entered the University, he had already decided to devote his life to the cultivation of physics, but he considered a sound knowledge of mathematics and chemistry to be an essential preliminary qualification. He took his Doctor's degree in 1847, choosing as the subject of his thesis an investigation in organic chemistry, involving the discovery of biuret, a produce of the decomposition of urea. It is significant of the changes that have occurred during the last fifty years, that when Wiedemann was a student at Berlin, there were no University lectures on mathematical physics, and no University laboratory for experimental physics. The liberality and zeal of Magnus, however, went far to supply the latter defect; he admitted students whom he thought sufficiently promising to work in his private laboratory, and encouraged them to attend the "Physical Colloquies," or evening meetings for the discussion of questions of physical interest, which he established in his own house. Wiedemann shared in these privileges, and thus became acquainted with Helmholtz, his intimate friendship with whom was interrupted only by death; he was also one of the band of strenuous young physicists, who about this time founded the Physical Society of Berlin. In 1850 he obtained the *licentia docendi* from the University of Berlin, and gave lectures as a *Privatdocent* on special branches of physics simultaneously with Beetz and Clausius.

In 1854 Wiedemann accepted a call to the Professorship of Physics in the University of Basel, where he remained till 1863, when he removed to Brunswick as Professor of Physics in the Polytechnicum. Three years later he was called to the Carlsruhe Polytechnicum to

succeed Eisenlohr, and in 1871 he entered upon the Professorship of Physical Chemistry in the University of Leipzig. For sixteen years he had been teaching pure physics, but his early chemical studies, which a well-marked chemical side to several of his latter experimental researches had helped to keep alive, enabled him to discharge the duties of this new office without too great difficulty; but when, in 1887, on the retirement of his colleague Hankel, he was offered the Professorship of Physics, he was glad to be able once more to concentrate his activity upon a single branch of science. The duties of this last office he continued to discharge practically up to the time of his death, which occurred on the 21st March, 1898.

One of Wiedemann's earliest experimental investigations related to the comparative thermal conductivities of the metals; his results long remained the most trustworthy that existed on the subject, and even now they have scarcely been superseded. Other researches dealt with electrical endosmose, the electrical resistance of electrolytes, the relation between the magnetic properties of compound bodies and their chemical composition, the influence of mechanical strain on the magnetic properties of the magnetic metals, and many other subjects. His magnetic researches, which were very thorough and long-sustained, brought to light a remarkable parallelism between the laws and effects of torsion and those of magnetisation, and led him to the discovery of several phenomena which were rediscovered later by other investigators.

A determination of the value of the ohm when expressed in terms of the specific resistance of mercury, the final results of which were published in 1891, led Wiedemann to a number which hardly differs to an appreciable extent from what is now admitted as the most exact value and affords a striking example of his care and accuracy in quantitative experiment.

But great as were Wiedemann's achievements as an original investigator, they were surpassed in importance by his literary labours. The editing of the 'Annalen der Physik und Chemie,' which he undertook in 1877 and continued to the end of his life, would be considered sufficiently laborious by most men who are already actively discharging the duties of an important University Professorship; but in his case it was a comparatively small addition to the work he was already engaged in. The 'Lehre vom Galvanismus und Elektromagnetismus,' or, as it afterwards became, 'Die Lehre von der Elektricität,' forms the most obvious and visible result of Wiedemann's work. The first edition appeared in 1861, and its revision and extension in three subsequent editions, the last of which was completed little more than a year ago, was a practically continuous occupation for the rest of the author's life. It is a monument of industry, untiring and judicious, and for accuracy and completeness it has no rival in any other branch

of physics. In addition to his immense knowledge Wiedemann had moral qualities—single-hearted devotion to truth, absolute fairness, and generous kindliness in recognizing the merit of others, which specially fitted him for literary work of the kind he undertook.

Wiedemann was a Privy Councillor of the Kingdom of Saxony. He was elected a Foreign Member of the Royal Society in 1884, and was a Member or Honorary Member of numerous other Societies and Academies in Germany and other countries.

He married, in 1851, Clara Mitscherlich, eldest daughter of the chemist, who survives him, and he leaves a daughter and two sons, one of whom is the well-known Professor of Physics at Erlangen.

G. C. F.

Sir FREDERICK McCOY. 1823-1899.

Professor Sir Frederick McCoy.—The announcement of the death of this distinguished naturalist, geologist, and palæontologist, which took place at Melbourne, May 16, 1899, appeared in the morning papers in London, May 18.

Sir Frederick McCoy held the post of Professor of Natural Science in the University of Melbourne, Australia, for upwards of forty years, and had attained his 76th year at the time of his decease.

His mental activity was unimpaired; his last communication: "On a new Australian *Pterygotus*," having appeared in the 'Geological Magazine' for May, 1899, p. 193. His name in Australia will always be connected with the splendid Museum of Natural History and Geology in Melbourne, of which he was the founder and life-long presiding genius.

Frederick McCoy was the son of Dr. Simon McCoy, M.D., of Dublin, and was born in that city in the year 1823. He was educated originally for the medical profession, and attended lectures, hospital practice, &c., in Dublin, and also in Cambridge; but while yet too young to be admitted to the profession, he devoted himself assiduously to the study of all branches of natural science, classifying the collections of the Geological and Royal Societies of Dublin, with the object of applying recent zoology to palæontology as the basis of stratigraphical geology. About this time he accepted the offer of Sir Richard Griffith to make the palæontological investigations required for the geological map of Ireland for the Boundary Survey, publishing the results in a

large quarto volume in 1844, with numerous plates, including figures of several hundred new species of fossils, entitled, 'Synopsis of the Carboniferous Limestone Fossils of Ireland,' and a smaller work in 1846, 'Synopsis of the Silurian Fossils of Ireland.' He was then invited by Colonel Sir Henry James, R.E., and Sir Henry de la Beche to join the Imperial Survey of Ireland, just then commenced, and, after completing the maps of the districts surveyed by him in the field, he was appointed by Sir Robert Peel's Government as one of the first Professors of the Queen's University in Ireland, the Chair of Geology and Mineralogy in the Northern College being assigned to him, where he lectured in the Queen's College, Belfast, and examined students in Dublin. About this time he undertook, in conjunction with the late Professor Sedgwick, of Cambridge, the large work on British Palæozoic Rocks and Fossils, based on the materials in the Woodwardian Museum at Cambridge, and to make the critical examination of the great series of fossils of the older formations brought together by Sedgwick. The results of these labours were deemed worthy of the compliment of publication by the Syndics of the University Press of Cambridge in a large quarto volume, with numerous plates of new species of fossils from the Carboniferous, Devonian, Silurian, and Cambrian formations, which was issued in 1852, as the second volume of a proposed joint work (but the first volume, which was to have comprised the Rocks, by Professor Sedgwick, was never published), entitled 'British Palæozoic Rocks and Fossils,' by Professors Sedgwick and McCoy.

Professor McCoy was shortly afterwards appointed by Sir J. Herschel and the Astronomer Royal, Sir G. B. Airy, as the first Professor of Natural Science in the new University of Melbourne, where, having taken part in the formation of the University, he lectured on chemistry, mineralogy, botany, comparative anatomy, zoology, geology, and palæontology for upwards of thirty years. He also established the National Museum of Natural History and Geology in Melbourne, of which he was Director to the last, which has risen to a distinguished position, not only by the extent of its collections but also by the perfection of their classification. Professor McCoy was Chairman of the first Royal Commission for International and Intercolonial Exhibitions for the Colony of Victoria. He was appointed Government Palæontologist at an early stage of the Geological Survey, determining the ages of the various tracts published on the maps. For over thirty years he prepared and continued to publish in decades, at short intervals, two works for the Government of Victoria: one entitled, 'Prodromus of the Zoology of Victoria,' with coloured figures from the life; and another, 'Prodromus of the Palæontology of Victoria.' He was a Justice of the Peace for Victoria. He was elected a Fellow of the Royal Society of London in 1880, and was

created one of the first Doctors of Science, *honoris causâ*, by the University of Cambridge. The Royal University of Ireland also conferred on him their highest degree in science and arts. He was created a Knight or Chevalier of the Royal Order of the Crown of Italy by King Victor Emmanuel, and has been offered similar distinctions by other foreign Sovereigns in recognition of his scientific work. In 1886 he received the decoration of C.M.G. from Her Majesty, and was created Knight Commander of that order in 1891. He has also received the Emperor of Austria's great gold medal of Arts and Sciences, the Murchison Medal from the Geological Society of London, and other similar distinctions. He was an honorary member of the Royal Society of New South Wales from 1875, and an honorary active member of the Imperial Society of Naturalists of Moscow, and honorary Fellow and member of many other British and foreign scientific bodies.

H. W.

ROBERT WILHELM BUNSEN. 1811–1899.

Robert Wilhelm Bunsen was born on March 31, 1811, at Göttingen, where his father was chief librarian to the University, and Professor of Classical Philology; he died at his residence in Heidelberg, on August 16th, 1899. From his earliest years up to the last, Bunsen breathed the free atmosphere of German University life, and throughout upheld the simple dignity and the entire devotion to science which are the distinctive marks of the highest ranks of the German Professoriate.

Not merely as an investigator of power and insight, but also as a teacher and master, the name of Bunsen will go down to posterity as that of one of the truly great men of the century.

The incidents of Bunsen's life are soon told. From the year 1833 onwards, when at the age of 22 he became Privat-Docent in the University of his birth-place, until the year 1889, when he retired from the Professorship of Chemistry, at Heidelberg, his energies, impaired by no great sorrow and by no serious drawback, were solely devoted to the service of science. For upwards of half a century he laboured continuously as an investigator and as a teacher, and in his declining years he might well look back with a satisfaction of which few can boast, on the work which he had accomplished.

To him came in due course honours of all kinds; from monarchs and governments, and from scientific academies, all the world over. A far greater satisfaction than the receipt of all these was however his, in the warm affection and respectful regard felt for him by all those who were fortunate enough to come under his influence. All knew at once that he was a man to be trusted and honoured, whilst the simplicity of his character, his true modesty, and his unaffected kindness of heart were patent even to a casual visitor. Only, however, to the few who were admitted to his more intimate friendship were the depths of his character revealed; and for these it may be enough to say that he was the "chevalier sans peur et sans reproche," and that the recollections of his companionship, both scientific and social, will remain as some of the pleasantest and most fruitful of their lives.

The investigations of the great Heidelberg chemist opened out new branches of science in many directions; some of these were epoch making, whilst the application of others to the needs and the welfare of the human race has done much for the benefit and comfort of mankind. It was characteristic of the man that in this latter direction

Bunsen himself did nothing. His was the duty of extending the boundaries of knowledge without reference to its application. Two sets of men, he used to say, were needed, investigators and those who applied scientific discoveries to useful ends. To him belonged the higher work, and he often spoke with undisguised amusement and astonishment of persons who, in the name of science, devoted all their energies to mere money making.

In 1836 Bunsen was appointed to the Chair of Chemistry in the Polytechnic School, at Cassel; two years later he became Professor in the University of Marburg. There he remained until 1851, when for a short time he went to Breslau, and in 1852 he was called to fill Gmelin's chair at Heidelberg, a quiet and beautiful spot where he spent the rest of his life, refusing pressing invitations to remove to what many consider the greater attractions of a metropolis.

Although he had accomplished much during his residence in Cassel and in Marburg: the carbon-zinc battery, the investigation of the cacodyl compounds, which paved the way for all subsequent work on the organo-metallic series, and though there he had laid the foundation for his gasometric methods, in his work on the gases of the blast furnace carried out in conjunction with Lord Playfair, and for his chemico-geological researches in Iceland, yet it was in the years following the building of the new Heidelberg laboratory in 1855, that Bunsen's greatest work was done. During the early years of that period the experimental results of his own labours and of those of the pupils who flocked from all parts to work under him, have never been surpassed if ever equalled in quality as well as in quantity by those issuing from any other chemical laboratory. And here it may be noticed that it is given to but few teachers to reckon as he could amongst the pupils of those years so many men whose names have since become well known. To mention only some, Germany and Switzerland sent Landolt, Lothar Meyer, Pebal, Baeyer, Carius, Pauli, Hermann, Quincke, and Lieben; from Russia came Beilstein and Schiskoff; from England—Atkinson, Matthiessen, Roscoe, and Russell; whilst America, France, Portugal, Sweden, and other countries were also well represented.

Of the more important work done during those years must first be mentioned his gasometric researches. These included, amongst other matters, exact and original methods for the measurement of gaseous volumes, for the investigation of gaseous diffusion and gaseous absorption, and these he fully described in the only book he ever published. For he was not a compiler, nor was he fond of manuals, and often remarked, laughingly, that what was written down in treatises was usually wrong. Then came the invention of the Bunsen burner, about which an interesting tale could be told. Coal gas had been introduced into Heidelberg just before the new laboratory was built, and Bunsen

determined to make a gas lamp for laboratory use in which a mixture of gas and air should burn without smoke or explosion in a simple tube. His clear conception of the laws which apply to the inflammation of such a mixture showed him that it was possible, although no one had hitherto succeeded in doing it, so to arrange the dimensions that a steady, non-luminous, but highly heated flame could be obtained without danger of the mixed gases becoming explosive within the tube. This result, apparently simple enough, was however only reached after a long series of delicate experiments. And now this burner is not only a necessity in every laboratory, but in every household, and in every manufactory where a clean flame is wanted. Next in importance come a series of investigation on various branches of analytical work, all characterised by original methods and delicate manipulative skill. Of these his iodometric method now in general use, and his elaborate and classical methods of silicate and mineral water analysis, are perhaps the most prominent.

Amongst the work done in conjunction with his pupils, the best known are the long series of researches on photochemical measurements with Roscoe, and that on the electrolytic preparation of the metals of the alkali-earths with Matthiessen.

In the early sixties, his crowning investigation on spectrum analysis made its appearance, including the work done, together with his colleague Kirchhoff, which gave rise to the discovery of cæsium and rubidium. Up to 1875 he continued to work at this favourite subject, on which he published many memoirs, especially remarkable being that on the absorption spectra of the compounds of the metals of the rare earths. Amongst these is to be found the first observation of the high luminosity caused by the ignition in the colourless flame of certain of these earths, a fact which has since become of immense commercial value in incandescent gas-burners.

His research on cæsium and rubidium and their salts is, perhaps, the one in which his marvellous power of exact experimentation is seen to the greatest advantage. From 44,000 kilos of the Dürkheim water he obtained only 16 grammes of the mixed chlorides. After he had separated these by a long and elaborate series of processes, only about 5 grammes of the chemically pure cæsium salt remained. With this comparatively minute quantity, Bunsen succeeded not only in preparing and analysing all the more important compounds of the metal, but in ascertaining by accurate goniometrical measurements their crystalline forms. So that we thus became acquainted with the properties and relationships of the compounds of this rare new metal as we had long been with those of potassium and sodium. But his labours at this time were not confined to one branch of the science. His researches covered a wide field, and were of the most diverse character, always, however, distinguished by the same seeking after exactitude both as

regards experimental results and as regards their literary expression. So that his published memoirs all serve, both in matter and manner, as classical examples which will long remain fertile sources of both pleasure and profit to generations of scientific students.

As a lecturer, Bunsen shone not by attempts at declamation or oratorical effect, but by the originality of his views, the aptness of his experimental illustrations, and the clearness of his exposition. It was, however, as a laboratory teacher that he chiefly excelled. It is in the laboratory that experimental science is really learnt, and there it was that his marvellous ingenuity in the construction of new apparatus out of the simplest materials, and his wonderful manipulative dexterity was best seen. There, inspired by his continual presence, the student learnt to participate in his devotion and zeal, and took to heart a lesson that in order to found or to carry out a successful school of experimental science the teacher must work alongside of the pupil. Up to 1889 he continued indefatigably to instruct a host of the younger chemists whose work did not fall short of that done by their elder *confrères*. Nor was his own scientific energy abated, as shown in the numerous researches published in these later years. Amongst them may be noted those on the metals of the platinum group; his work on flame reactions; the important one on the ice-calorimeter; and, lastly, the one on the vapour-calorimeter.

After he retired from active work he continued to reside in Heidelberg, taking an interest almost up to the last in the scientific progress of the day, and quietly enjoying the friendship and society of the few scientific friends who still remained, for most of his intimates had long since passed away.

The titles of no fewer than eighty-four memoirs by Bunsen are given in the catalogue of the Royal Society up to the year 1883, whilst twenty more were published by him in conjunction with one or other of his pupils or friends.

In 1858 Bunsen was elected a Foreign Fellow; in 1860 the Copley Medal was awarded to him; and seventeen years later he, together with his colleague, Kirchhoff, became the recipients of the Davy Medal.

A memorial address by Dr. Curtius, the present Professor of Chemistry at Heidelberg, was delivered in the Aula of that University on November 11th (1899).

H. E. R.

Sir ALEXANDER ARMSTRONG. 1818–1899.

Sir Alexander Armstrong, K.C.B., was of Irish parentage, his father being Mr. A. Armstrong, of Craham, co. Fermanagh. He was born 1818, educated at Trinity College, Dublin, and studied medicine at the University of Edinburgh. In 1842 he entered the Medical Department of the Navy, and in the course of his career saw a great deal of service in various parts of the world, becoming prominently identified with the survey of the "North-west Passage." The expedition to search for Sir John Franklin from Behring Straits eastwards, was fitted out in 1849, and Armstrong was appointed Surgeon and Naturalist to the "Investigator," under the command of Captain (afterwards Sir Robert) M'Clure. Four successive Arctic winters were passed by this expedition, before officers and men were finally transferred to the "North Star," and returned to England in the autumn of '54, while the "Investigator" was finally abandoned, a medical survey of the crew, ordered by M'Clure and conducted by Surgeons Armstrong and Domville, having proved the urgency of the step.

During the hardships of this eventful expedition, the first and last which succeeded in making the North-west Passage, Armstrong's efforts were happily directed towards preserving the ship's crew from scurvy, mainly by the liberal administration of lime-juice, and he was successful in keeping the scourge at bay until the spring of 1852. He was frequently mentioned in the despatches connected with this expedition, and at the time of his death was one of the very few surviving officers of the party who circumnavigated the continent of America.

The Russian war having broken out the year before the return of the expedition, Armstrong was ordered to service with the Baltic fleet. He was present at the bombardment of Sveaborg, and in two night attacks with a flotilla of rocket-boats, for which he was afterwards gazetted.

Later in his career he rose to the highest offices in the naval medical service. He was Deputy Inspector-General of the Mediterranean Fleet and the Naval Hospitals of Malta, Haslar, and Chatham, and was subsequently made Inspector-General for special services. In 1869 he was appointed Director-General of the Medical Department of the Navy, from which post he retired in 1880.

Armstrong published in 1857 his popular work, 'A Personal Narrative of the Discovery of the North-west Passage,' and he was also the author of a valuable book, 'Observations on Naval Hygiene, particu-

larly in connection with Polar Service.' In 1857 he was elected a Fellow of the Royal Geographical Society, and in 1873 he became F.R.S. In 1871 he received his K.C.B., Military Division.

Sir Alexander married, in 1894, Charlotte, Lady King-Hall, widow of Admiral Sir William King-Hall. He died July 4, 1899, aged 81.

M. F.

Sir BENJAMIN WARD RICHARDSON. 1828–1896.

Benjamin Ward Richardson was born at Somerby, in Leicestershire on October 31, 1828. He died November 21, 1896. In his boyhood he was an ardent naturalist; and for life he remained a naturalist in his diverse interests, and his intense curiosity in all natural phenomena. Had he concentrated his powers upon one department of research, he would have left a greater name to posterity, but he would have been a less interesting, and in his generation, probably, a less useful man. Richardson's scientific bent led him to medicine, and he was peculiarly fortunate in the two practitioners with whom he was placed as a pupil, both of them being men of like tastes to his own. Early in his career he found a chief interest in the practice of anæsthesia, and he then invented a chloroform inhaler. On settling in London to practise, he pursued his study, and thus became engaged in a research into the alcohol and ether series; it was characteristic of him that in this research he never lost sight of practical applications: he introduced "bichloride of methylene" as an anæsthetic; he invented the "ether spray" for local anæsthesia, and the "lethal chamber," still in use, for the painless extinction of dogs and other animals. His energy and endurance were marvellous, no subject in or near the sphere of medicine did he leave untouched; in many of them he showed some originality of conception, and none did he fail to enliven with some fresh illustration. Thus his lectures were very popular and effective. A general reference may here be made to his work on pharmacology, especially on nitrite of amyl; on toxicology; on oxygen and artificial respiration.

In 1854 he obtained the Fothergillian Medal of the Medical Society of London for an essay on the "Diseases of the Fœtus in Utero"; and in 1856 the Astley Cooper Prize for his essay on "The Coagulation of the Blood."

Richardson's vigilant eye to immediate usefulness—to the applica-

tions of science—arose in part from his busy disposition, but largely also from his profound humanity. Having convinced himself by his investigation into the effects of alcohol upon animals that these were injurious, he promptly became a total abstainer, and as a missionary in this cause never relaxed his efforts to the end of his life. The same impulses and qualities of character led him to the van of the comparatively new science and art of sanitation. By his enthusiasm and accomplishments in this field, perhaps he will be chiefly remembered. In 1862 he founded the 'Journal of Public Health,' which, with some changes in title and continuity, he edited until his death.

In 1861 he founded the quarterly journal, 'The Asclepiad,' a marvellous medley of clinical medicine and of curious learning in medical history and biography, written entirely by himself. This journal also he kept up with great spirit and ability to the end of his life. Not content with these many functions, and amid the distractions of practice, Richardson found time to devote to poetry and letters and transcendental philosophy.

By his friends he will be remembered as a kindly, genial man, living a very full but also a very sociable life; for, teetotaller as he was, he was a spirited and entertaining table companion, and a good after-dinner speaker.

Richardson was made a Fellow of the Royal Society in 1867, and was knighted in 1893. His autobiography was published under the title of 'Vita Medica,' in 1897.

T. C. A.

EDWIN DUNKIN. 1821–1898.

Edwin Dunkin, the third son of William Dunkin, was born at Truro on August 19, 1821. His father had been for many years one of the established calculators of the 'Nautical Almanac,' performing the work at his residence at Truro until the organisation of the 'Nautical Almanac' office in London, under Lieutenant Stratford, R.N., caused him to be removed thereto. Mr. Dunkin received his general education at private schools at Truro and in London, being finally sent to a French school at Guines, near Calais, from which he returned on the death of his father in the summer of the year 1838. In August following he joined the staff of computers, organised by Sir George Airy, at the Royal Observatory, Greenwich, for reduction of the planetary and lunar observations made at Greenwich from the time of Bradley in 1750 to 1830, a position which he occupied until the year 1840, when, on the establishment of the Magnetical and Meteorological Department of the Observatory, he was transferred thereto, being one of the assistants (another being Mr. J. R. Hind, afterwards for many years superintendent of the 'Nautical Almanac') placed under Mr. James Glaisher as chief.

Although some attempt had been already made to apply photography to record the variations of meteorological instruments, there seemed at the moment little prospect of practical application of such method to the instruments of an observatory, and the work during Mr. Dunkin's time was consequently arduous, since eye observation of the magnetical and meteorological instruments had to be made at intervals of two hours day and night (except on Sunday, when a few observations only were made). On one day in each month observations of the magnets were taken at intervals of five minutes throughout the twenty-four hours in conjunction with similar observations made at observatories in other parts of the world, besides which during periods of magnetic disturbance, so long as it lasted, observations had to be continuously made. One of the first remarkable magnetic storms observed was that of September 25, 1841, and the writer of this notice very well remembers the lively interest created when it became known that in such distant parts of the world as Toronto, Trevandrum, and the Cape of Good Hope magnetic disturbance of a like character had occurred on the same day, said as regards Toronto as appearing to have commenced "nearly at the same absolute time as at Greenwich."

In October, 1845, Mr. Dunkin was transferred to the Astronomical Department of the Observatory, and in the year 1847 was placed in

charge of the then new altazimuth instrument, one specially designed by the Astronomer Royal for observation of the moon near to conjunction with the sun, before and after which epoch for a number of days more or less observation on the meridian is impossible; indeed, with this instrument, observations in other parts of the lunation were also frequently secured when the sky at meridian passage was cloudy.

In 1851 Mr. Dunkin was deputed to proceed to Christiania to observe the total solar eclipse of July 28. The weather on the occasion was not altogether favourable; he, however, saw three red prominences, one of which being watched and showing no apparent change of form gave him the impression of "some connection with the moon." He remarked, however, that the circumstances being rather difficult, he was possibly deceived. It will be remembered that it was not until the total eclipse of July 18, 1860, that the red prominences were conclusively proved to be solar appendages. In 1854 Mr. Dunkin was superintendent of a party of six observers organised by the Astronomer Royal to make simultaneous pendulum observations at the surface and at the bottom of the shaft of the Harton Colliery (near South Shields), 1260 feet deep, for determining, from the observed variation of gravity, the mean density of the earth; and in 1855 he was charged with the setting up, in the Paris International Exhibition of that year, of a large-sized model of the new Greenwich transit-circle.

Before the establishment of the electric telegraph, the finding of differences of longitude, with the exactness which in a scientific point of view had become desirable, was a difficult problem. The method by transmission of chronometers had given the best results, but it was an operation troublesome and laborious and of necessity of restricted application. On the connection of the English telegraphic system with that of the Continent in 1851, by means of the Channel submarine cable, astronomers eagerly looked forward to employment of the telegraph for longitude purposes, and the Royal Observatory having been placed in communication therewith, it devolved on Mr. Dunkin, in conjunction with Sir Charles Todd (now Postmaster-General, South Australia), to inaugurate the method in May, 1853, by an experimental determination of the longitude of the Cambridge Observatory, an operation that was entirely successful. It was at once seen that the telegraph, wherever available, had placed in the hands of astronomers a method that for convenience and accuracy surpassed all others—one that would become of great importance in geodetic work. It had been intended as regards the Continent to apply the method first to a determination of the longitude of Paris, but the illness and death of Arago having retarded this operation, attention was given to Brussels. the longitude of which was determined in the year 1853, being followed by that of Paris in 1854, in both of which operations Mr. Dunkin undertook a chief part, having for colleague in the latter

work M. Faye. Other similar operations followed, one being the determination in 1862 of the longitude of Valentia, in Ireland, in order to complete the great arc of parallel from Valentia to the Volga, in which work, for finding the local time at Valentia, Mr. Dunkin employed an altazimuth, observing zenith distances of stars east and west of the meridian.

In 1845 Mr. Dunkin became a Fellow of the Royal Astronomical Society; in 1868 he was elected a Member of Council, and was one of the Secretaries from 1871 until 1877. In 1884 he was chosen President, occupying the chair until 1886, and delivering the presidential address in 1885, on award of the Gold Medal of the Society to Sir William Huggins, for his spectroscopic researches on the motions and constitutions of stars and comets, and again in 1886, on the presentation of medals to Professor Edward C. Pickering and Professor Charles Pritchard, for their photometric work. Mr. Dunkin retired from the Council of the Society in 1891, having been an active member thereof for twenty-three years. At the time of removal of the Society from Somerset House to the new apartments at Burlington House, in 1874, the burden of work consequent thereon, aggravated as it was by the death of the Assistant Secretary, fell mainly on Mr. Dunkin. During his lengthy official career he contributed numerous papers to the Society, as a practical astronomer being interested in questions such as personal equation in observation, the probable errors of observation and in results, and the proper motions of stars, a paper "On the Movement of the Solar System in Space deduced from the Proper Motions of 1167 Stars" being his most important contribution; also whilst holding office as Secretary, the portion of the Annual Council Report dealing with the progress of astronomy during the year grew in interest and importance. Many notices of astronomers written by him for this Report, with some others, were published in 1879 in a separate volume, "Obituary Notices of Astronomers," which gives in a collected form an appreciative account of the labours of many noted men. Mr. Dunkin was elected a Fellow of the Royal Society in 1876, and served on the Council of that body from 1879 to 1881. From 1889 to 1891 he was President of the Royal Institution of Cornwall, in which capacity he delivered in 1890 and 1891, in his native town of Truro, presidential addresses dealing with the progress of astronomy in modern times.

The labour of continuous observing work is in a public observatory somewhat arduous, and during the later period of his official life Mr. Dunkin was entirely relieved therefrom and placed in charge of the computing staff, although he still continued to be responsible for certain instrumental adjustments and determination of instrumental constants. In 1881, on the retirement of Sir George Airy from the post of Astronomer Royal, his successor, Mr. Christie, recommended Mr. Dunkin for the office of Chief Assistant, to which he was appointed

by the Admiralty, and from which position he retired in 1884, after an official life of forty-six years.

Mr. Dunkin was one of various writers who in recent times helped to promote in the public mind that taste for astronomical pursuits now so evident. Some thirty years or more ago, in re-editing 'Lardner's Handbook of Astronomy,' he incorporated therein a large amount of new information on the progress of astronomy up to that period, of which more than one edition was published. And a following work, 'The Midnight Sky,' a popular exposition of the varying aspect of the starry heavens in each month of the year, has since enjoyed a wide circulation amongst that class of readers for which it was mainly designed; besides which he contributed articles of popular character on astronomical subjects to various of the periodicals of the time.

Mr. Dunkin married in 1848 Maria, the eldest daughter of the late S. J. Hadlow, formerly a member of the Stock Exchange. He enjoyed his retirement for fourteen years, retaining still his interest in the science in the promotion of which his life had been spent. He died at his residence on Blackheath, on November 26, 1898, in his 78th year, and was buried in the adjacent Charlton Cemetery, and his wife died in the year following. He leaves an only son, Edwin H. W. Dunkin, known for his archæological researches.

W. E.

Rev. WILLIAM COLENSO. 1811–1899.

William Colenso, born at Penzance, Cornwall, in 1811, was the eldest son of Samuel May Colenso, who married Mary Veale Thomas, both being natives of that town. On his father's side he was cousin to the late Bishop Colenso, of Natal, and on his mother's to Sir Penrose Goodchild Julyan, a colonial official. As a youth he was apprenticed to a printer of Penzance, from whence he went to London, where he was employed in the same capacity by the British and Foreign Bible Society. This led to his being sent by the Society to New Zealand, whither, in December, 1834, he carried the first printing press that was established in that group of islands. This occurred five years before they became a British Colony.

The mission station was at Pahia, in the Bay of Islands, where, within six weeks of his arrival, though hampered by an incomplete outfit, he printed the Epistles to the Ephesians and Philippians in the Maori language. By the third following year he had printed the whole New Testament in Maori, and, with the assistance of natives only, had bound the copies with his own hands.

In 1844 he abandoned the work of printer, left Pahia for Hawke's Bay, took to missionary work, and after a training by Bishop Selwyn at St. John's College, Auckland, was ordained to a church in Napier, where he resided till his death in 1899.

From the date of his arrival in New Zealand Mr. Colenso took an active interest in the history, folk-lore, habits, languages, &c., of the natives, and being gifted with the love of natural history and of travel, a cultivated mind, an iron constitution, and methodical habits as an observer, collector, and recorder, all of which he used to the best advantage during a long life, it is not surprising that he was regarded as the Nestor of science in a colony his arrival in which antedated its foundation.

It was by a visit to the Bay of Islands in 1838 by Allan Cunningham,* the celebrated Australian botanist and explorer, then in charge of the Botanical Gardens of Sydney, that Mr. Colenso's attention was first drawn to botany; and to this visit, and those of Darwin in the "Beagle" in 1835, and of the Antarctic Expedition under Sir James

* Allan Cunningham was naturalist in Capt. King's surveying voyage of the coasts of Australia, and discoverer of the Darling Downs, to which the sudden expansion of the sheep industry in New South Wales was due.

Ross in 1841, he ever afterward referred as the most memorable events in his scientific career. From the latter date, after his philological and linguistic studies, that of the vegetation of the northern island was paramount. During the many journeys which he made, often through previously unvisited mountain regions, he observed and collected continuously, making discoveries that shed unexpected light on the affinities of the New Zealand Flora with those of Australia, South America and the Antarctic Islands. Nor did his zeal diminish with age, for, as the result of an expedition made in his eighty-seventh year, he sent to Kew specimens and observations of plants made *en route*. His botanical writings, though numerous, are, as those on other branches of biology, fragmentary. They commence with one on Ferns, communicated to the 'Tasmanian Journal of Natural Science' in 1844; others occupy many volumes of the last-named work, of the 'Transactions of the New Zealand Institute,' and of the Hawke's Bay Philosophical Institute. Of these latter, the most important are: An account of visits to the Ruahine Mountains in 1845 and 1847, which is a repertory of information on the geography and vegetation of the previously unexplored regions visited; the first account of the discovery of the Dinornis bones; on the ancient (now extinct) dog of New Zealand; on the Maori races; on the vegetable food of the ancient New Zealanders; on the traditions of the Maoris, and on their sense of colour. Altogether, Mr. Colenso is credited with the authorship of thirty-two articles in the Royal Society's Catalogue of Scientific Papers down to the year 1883, and many have since appeared in the volumes of the New Zealand Institute.

For upwards of sixty years Mr. Colenso systematically took advantage of his unique opportunities for collecting information regarding the language, customs, myths, proverbs, songs, &c., of the Maoris, subjects that had a special fascination for him, and as the information obtained was direct from native sources—some of it from men who remembered Captain Cook's visits, and antedated the corruptions introduced by Europeans—the collection is of unique value.

In 1861 Mr. Colenso entered Parliament as representative of Napier, when he moved and carried a resolution that the time had come for the State to make an organised attempt to rescue the dying language of New Zealand from oblivion. Being at the time unable to undertake such a work himself, he offered to present the Government with his whole collection of materials for it. In 1865 the Government took up the subject, and in 1866 Mr. Colenso, then being more at liberty, was successfully urged, as the one man in New Zealand thoroughly qualified, to take up the work. Seven years was fixed for its completion, the remuneration to be £300 per annum. Before half that period had expired, another Ministry, with other views of the value of a Lexicon, had supervened, by whom its author was informed that, half the time

allowed for the completion of the work having expired, one-half of the work itself should have been in the press. On the unreasonableness of this view in the case of a work requiring innumerable cross references being represented, a committee of qualified persons was appointed to examine and report on the progress made. The report was to the effect that the author had advanced further in his work than was due up to the time employed, that thousands of pages had been written from the first word to the last, and that seven years was too short a time for the completion of a work of such magnitude. The report was withheld from Parliament, funds for proceeding with the Lexicon were refused, and the unfinished materials were thrown upon the author's hands, one finger of which was permanently disabled by writer's cramp, due to his labours on the Lexicon. A sample portion was, however, demanded to be laid before the House, and letter A produced, but this was "lost," and not discovered till eighteen years afterwards in a departmental pigeon-hole. It was then printed and distributed by Government, partly at its author's expense, in the year preceding his death.* Its appearance, dedicated to his old friend, Sir George Grey, has been followed by urgent representations to the Colonial Government that the whole materials, which are bequeathed to the State, should be entrusted to a competent editor for publication.

In 1890 he published an authentic history of the signing of the Treaty of Waitaugi, of which he was the sole surviving witness, a document regarded in the Colony as of great historic value. Towards the close of his life he offered his valuable library and all his collections to the town of Napier as the nucleus of a museum, together with £1000 as endowment, on condition that a suitable site and building were provided. The site proposed was, however, unsuitable, having an ocean frontage, the salt-laden atmosphere of which would have been detrimental to the collections; he therefore withdrew the offer, and transmitted the amount of the endowment to his native town of Penzance to form a fund, to which he subsequently largely added, for the relief of deserving poor.

In person, Mr. Colenso was, in 1841, as remembered by the writer of this notice, a man of medium height, brisk, active, and with a frank, winning address. Later in life he was conspicuous for his abundant long white hair on scalp and face. Only two years before his death, which occurred at Napier in February, 1899, he was thrown from a carriage, and besides receiving a severe shock, had his right arm shattered at the elbow. Though then in his eighty-seventh year he

* A fuller account of the fate of the Lexicon will be found in 'Reminiscences of the Rev. W. Colenso,' by R. Coupland Harding, 'The Press,' Christ Church, New Zealand, February 27, 1899; and 'The Evening Post,' Wellington, February 13, 1899.

recovered the use of the limb in so far as to wield his pen with his wonted energy, but with no little pain. He married in middle age, and left a family. He was elected a Fellow of the Linnean Society in 1865, and of the Royal in 1886.

J. D. H.

SOPHUS LIE. 1842-1899.

Marius Sophus Lie, the son of a Norwegian pastor, was born on the 17th of December, 1842, at Nordfjordeide.* Educated in a private gymnasium in Christiania, he entered the University of that city in 1859. He does not appear to have displayed any special predilection for mathematical pursuits in his student days; and even after passing, in 1865, his qualifying examination as a teacher, he remained in doubt as to the particular direction of his life. He gave private instruction in mathematics, and, after spending some time on astronomy, he turned to the consideration of the foundations of geometry—a subject to which he devoted more special attention in later years.

It was only in 1868, at an age much later than the average at which great mathematicians are wont to settle down to their life-work, that Lie found his true bent. In that year the works of Plücker on modern geometry first gave him the impulse towards research, and inspired him with original ideas, the gradual development of which gave him the first indication of his possession of mathematical powers. Thenceforward his life was one stretch of industry and activity, and the only interruptions to his creative work were the illnesses which overshadowed his later years, and were, without doubt, largely due to the exceeding strenuousness of his devotion to his investigations.

* The writer of this notice wishes to acknowledge his indebtedness to two articles on Lie by Professor Dr. F. Engel: one in the 'Jahersb. d. deutschen Mathematiker-Vereinigung,' vol. 8 (1900), pp. 30—46; the other in 'Bibliotheca Mathematica,' 3rd ser., vol. 1 (1900), pp. 166—204. Reference should also be made to an appreciation by Noether, 'Math. Ann.,' vol. 53 (1900), pp. 1—41.

The publication* of his first paper, "Repräsentation der Imaginären der Plangeometrie," in 1869, led to a travelling scholarship which enabled him to visit foreign universities. The succeeding winter was spent at Berlin, where Lie and Klein met and contracted their long friendship, which was based, in the first instance, upon their common interest in the range of ideas associated with Plücker's geometry. Thence in the early summer of 1870 they went to Paris, coming into personal relations with Darboux and Jordan; and their growing interest in the theory of groups, first awakened in Lie by Sylow's lectures, which he had attended as a student, was stimulated for both of the two friends, as they recognised different modes in which that theory could be newly applied to branches of mathematics. In particular, Lie then discovered his now famous transformation, which makes a sphere correspond to a straight line, and by which, therefore, theorems on aggregates of lines can be translated into theorems on aggregates of spheres. The paper† containing this result was communicated to the Academy of Sciences by Chasles.

The visit to Paris was brought to an abrupt end by the outbreak of the war between France and Prussia. Klein was of course, as a German, bound to leave Paris; but the same obligation did not rest upon a Norwegian, and Lie remained until August, when he conceived a plan of walking through France to Italy. He had gone only as far as Fontainebleau, when a misadventure suspended his journey for a time. Let it be told in the words of Darboux‡:—

> "Occupé sans cesse des idées qui fermentaient dans sa tête, il allait chaque jour dans la forêt, s'arrêtant dans les sites les plus éloignés des sentiers battus, prenant des notes, dessinant des figures au crayon. Il n'en fallait pas tant à cette époque pour éveiller les soupçons. Arrêté et incarceré à Fontainebleau, dans des conditions d'ailleurs fort douces, il se réclamait de M. Chasles, de M. Bertrand, d'autres encore; je fis le voyage de Fontainebleau et n'eus aucune peine à convaincre le procureur impérial; toutes les notes que l'on avait saisies et où figuraient des complexes, des systèmes orthogonaux, des noms de géomètres, ne se rapportaient en aucune façon à la défense nationale. . . . "

After a delay of four weeks, he continued his journey to Italy; then, travelling homewards through Switzerland and Germany, he returned to Christiania in December, after a joint note by Klein and himself had been communicated in that month to the Berlin Academy by Kummer.

* Reprinted, under a different title, in 'Crelle's Journal,' vol. 70 (1869), pp. 346—353.

† 'Comptes Rendus,' vol. 71 (1870), pp. 579—583.

‡ See the 'Notice sur M. Sophus Lie,' spoken on the occasion when Lie's death was announced to the Academy of Sciences ('Comptes Rendus,' vol. 128 (Feb. 27, 1899), pp. 525—529).

From that date onwards, the history of the man is mainly the history of his ideas; the external incidents of his life are comparatively few.

At the beginning of 1871 he was assigned a junior post in his own University, and in the summer of that year he graduated as Doctor. The thesis then submitted was subsequently amplified and became his famous memoir,* "Ueber Complexe, insbesondere Linien- und Kugel-Complexe, mit Anwendung auf die Theorie partieller Differential-Gleichungen." In this memoir he constructs the theory of tangential transformations† for space; he applies it to partial differential equations of the first order; he develops the transformation of Plücker's line-geometry into a sphere-geometry, which now is regularly associated with his name; and he shows how the results can be applied to ordinary differential geometry, obtaining (among other properties) the result that his transformation of line-geometry into sphere-geometry makes the asymptotic curves of one surface correspond to the lines of curvature of the transformed surface. These are but a few of the results in a paper which is full of powerful methods and novel ideas; they are sufficient to show that the man who, before 1868, was hesitating about his vocation in life, had found an effective vocation by 1871.

In the succeeding year, the Norwegian Storthing was induced to create a special professorship for him in the University of Christiania. His appointment as Professor Extraordinarius in 1872 enabled him for the future to devote himself to his researches, free from the distracting necessity of supplementing the over-modest salary of his earlier post by private teaching.

About this time Lie seems to have made his first discovery as to the relations that can subsist between ordinary differential equations and infinitesimal transformations; the scope of such a relation can be indicated by the simple example of an equation of the first order. A function $\Omega(x, y)$ is said to admit a finite continuous group of transformations represented by

$$x_1 = \phi(x, y, a), \qquad y_1 = \psi(x, y, a),$$

* 'Math. Ann.,' vol. 5 (1872), pp. 145—256.

† The transformation of surfaces adopted makes (not merely a point correspond to a point, but) an element of any surface at a point correspond to an element of the transformed surface at the corresponding point. The property holds over the whole of the two surfaces, and, for instance, in the case of ordinary space, leads to the analytical relation

$$dz' - p'dx' - q'dy' = \rho\,(dz - pdx - qdy),$$

where x, y, z, p, q, define an element of the one surface, x', y', z', p', q', define the corresponding element of the transformed surface, and ρ is a non-vanishing quantity that does not involve differential elements. Such a relation is the basis of the analytical theory of tangential (or contact) transformations.

where a is an arbitrary parameter, when

$$\Omega(x_1, y_1) = \Omega(x, y).$$

Such a group possesses an infinitesimal transformation, which may be represented by

$$x_1 - x = \xi(x, y)\delta t, \qquad y_1 - y = \eta(x, y)\delta t,$$

where δt is arbitrary, and the infinitesimal transformation determines the group. Moreover, the necessary and sufficient condition that the function $\Omega(x, y)$ should admit the above group is that the function should admit the infinitesimal transformation of the group, and the analytical expression of the condition is

$$\mathrm{U}(\Omega) = \xi(x, y)\frac{\partial\Omega}{\partial x} + \eta(x, y)\frac{\partial\Omega}{\partial y} = 0,$$

If the function Ω involves y', where y' denotes dy/dx, say, it is

$$\Omega(x, y, y'),$$

the analytical expression of the condition, that it admits the same group is

$$\mathrm{U}'(\Omega) = \xi\frac{\partial\Omega}{\partial x} + \eta\frac{\partial\Omega}{\partial y} + \left(\frac{d\eta}{dx} - y'\frac{d\xi}{dx}\right)\frac{\partial\Omega}{\partial y'} = 0.$$

Now Lie discovered that, if an equation

$$f = \mathrm{X}(x, y)\, y' - \mathrm{Y}(x, y) = 0$$

admits the infinitesimal transformation just indicated, so that $\mathrm{U}'(f) = 0$ then

$$\frac{\mathrm{X}dy - \mathrm{Y}dx}{\mathrm{X}\eta - \mathrm{Y}\xi}$$

is an exact differential save only in the trivial case $\mathrm{X}\eta - \mathrm{Y}\xi = 0$; so that the transformation determines a factor of integrability, and thus, merely after a quadrature, leads to the integral of the equation. Further, the significance of the result is not thereby exhausted, for it permits the construction of the differential equations of the first order that admit any given finite continuous group of transformations, for instance, a projective group. All that is necessary for this purpose is to construct the infinitesimal transformation which determines the group, and to obtain a couple of independent integrals, say u and v, of the system

$$\frac{dx}{\xi} = \frac{dy}{\eta} = \frac{dy'}{\frac{d\eta}{dx} - y'\frac{d\xi}{dx}};$$

the required equation is

$$u = \mathrm{F}(v),$$

where F is any functional form. Manifestly, such an idea is capable of wide application: under Lie's direction, it proved fruitful in succeeding years.

Similarly, the integration of partial differential equations of the first order was discovered by Lie to be bound up with infinitesimal tangential transformations under which they are invariantive. This discovery led him to resume the whole problem of the integration of such equations; and, as the outcome of his investigations, specially built upon the completed analytical theory of tangential transformations, he made two notable advances. One of these consisted in a great simplification of the known method of Jacobi, by affecting a material reduction in the number of quadrature processes; the other led him to a new method for the solution of Pfaff's problem, which, besides being simpler and shorter than preceding methods, indicated the real functional significance of the necessary analysis.

These results, obtained by connecting infinitesimal transformations with widely verging questions in differential equations, prepared the way for the consideration of a problem certain to possess an extensive range, viz., the theory of finite continuous groups of transformations, in general, and without special regard to any particular application. Lie began this work in 1873, and, for the next three years, concentrated upon it all the intensity of his creative enthusiasm: he once spoke of himself as having, during that period, lived only among his groups of transformations. The result was to constitute this theory an independent subject: begun, as already indicated, from its association with differential equations, and finding in its progress some of its most direct applications in that region; but, as the theory grew, it obtained a wider significance, and the geometrical bent of much of Lie's thought gave it applications within the region of geometry.

Towards the close of 1877 Lie had completed one stage of these investigations. His conclusions were embodied in a number of memoirs; many of them were published in a new journal in Christiania, edited by Sars, Müller, and himself, some of them in the 'Mathematische Annalen,' most of the latter being revised and extended accounts of earlier papers. Apparently, Lie suffered from severe disappointment at the lack of interest so far shown in his work by mathematicians; his story at this time reads like the occasional experience of the investigator who lives, remote from fellow-workers and unstimulated by eager pupils, voyaging through his sea of thought alone, at the end finding himself weary, isolated, unacknowledged, perhaps therefore discouraged, and certainly left uncheered by any confident satisfaction that others are following him.

At any rate, whatever the explanation may be, Lie sought relief in change of subject, and devoted himself, almost entirely for the next few years and partially for the rest of his life, to differential geometry. In a long succesion of valuable papers, he made masterly additions to our knowledge of minimal surfaces, particularly those which are algebraic; he dealt with surfaces which have their Gaussian measure of curvature equal to a constant, or are determined by other assigned relations between their principal radii of curvature; and he discussed surfaces as generated by the translational motion of a curve. The theory of his groups was frequently applied in these researches, and with considerable effect; thus his papers on the classification of surfaces according to the groups of transformations of their geodesics are of high importance. Darboux, in the 'Notice sur M. Sophus Lie,' already quoted, indicated his sense of the value of these contributions to differential geometry: no less significant is the testimony in Darboux's great treatise, 'Théorie générale des surfaces,' furnished by the number of references to Lie's name in its index.

Yet during this specially geometrical period, he did not altogether neglect the development of his theory of continuous groups; occasional papers were written from time to time, showing that it still occupied part of his constructive thought. Towards the end of the period, about 1882, his papers gave signs of his having again reverted to differential equations by applying his groups to the classification and integration of ordinary differential equations of any order. Moreover, the publication of Halphen's thesis on differential invariants led Lie to point out that his own earlier work included Halphen's investigations. His attention was thus again turned to the subject, and one consequence was that he gave the general theory of differential invariants, not merely for the projective group, as in Halphen's work, and in the subsequent detailed work of a number of English mathematicians, but for any finite continuous group of transformations.*

Lie's investigations had now extended over a considerable number of years. They had covered a wide range in a variety of subjects, and the results had been published in no consecutive form and in partly inaccessible places. He had from time to time thought of undertaking some treatises dealing with the main topics which had occupied his thoughts for more than fourteen years. But it was not until September, 1884, that any such project took a practical shape. In that month Friedrich Engel came to Christiania, partly in order to make himself acquainted with Lie's work, partly (on the advice of Klein and A. Mayer) to assist Lie, if that were possible, in making a systematic exposition of the whole theory of transformation-groups. It was exceedingly fortunate for Lie that he thus found some active co-operation and steady assistance in the execution of a severe, even

* 'Math. Ann.,' vol. 24 (1884), pp. 537—578.

exhausting, piece of work. The labour lasted for nine years. During that time, Engel's co-operation and assistance were given, without stint and in a loyalty beyond praise, and fully merited the acknowledgment which Lie made in his preface. The result was the 'Theorie der Transformationsgruppen,' a treatise in three volumes, covering over two thousand pages, the contribution to science by which his name will probably best be known. It is a work of great originality, containing many methods and a wide range of development; it exhibits in masterly manner the suggestive application of new methods to fundamental subjects; and it may be described briefly as a systematic exposition of Lie's investigations on groups of transformations that are continuous and finite. Among the subjects to which application is made, may be mentioned the theory of ordinary differential equations; the theory of partial differential equations, both single and in systems; differential invariants and their types; the solution of Pfaff's problem; tangential transformations, especially in spaces of two and three dimensions, and more generally in n dimensions; groups of functions transformable into one another, and a substantial simplification (by the use of their properties) in the integration of systems of partial differential equations; a complete determination of types of the groups of transformation in one, two, and three variables, and a partial determination of those in n variables. It concludes with a profound study of the foundations of geometry from the point of view of Riemann and Helmholtz; and after a critical discussion of the significance of the hypotheses which they made, he propounds a solution of his own, based upon more elementary hypotheses.

While this work was in progress, Lie changed the scene of his life by accepting, in 1886, the Chair of Mathematics at Leipzig, which had been vacated by Klein on his appointment at Göttingen; Engel accompanying him, and soon being nominated a colleague. Such a professorship possessed some obvious advantages for Lie as compared with the somewhat isolated chair at Christiania. It secured him a wider recognition; it gave him an audience; it offered him the chance of able pupils, who would work sympathetically in development of his mathematical theories. Though these advantages did not come early enough to encourage him, still they did come gradually, and some of them in full measure. His work began to be known better and to be appreciated; his methods began to influence mathematicians. Pupils came to him from far and near, and one in particular, George Scheffers, rendered to him offices similar in kind to those rendered by Engel. When once the merit of his work began to be recognised, scientific honours were bestowed upon him freely. He received the honorary or foreign membership of societies and academies in great numbers; in particular, he was enrolled among our Foreign Members in the year 1895.

Unhappily, recognition appears to have been, not merely slow in coming, but almost too late when it came. There is no doubt that his ceaseless activity in thought and work had undermined his strength, and his spirit had brooded in its loneliness. He suffered from sleeplessness, and developed nervous symptoms: the result was a complete breakdown in 1889. The direct interruption of his work lasted for a large part of a year; happily he was afterwards able to resume it, and for a time was as fertile in production as he ever had been. But the effect upon the man never completely passed off; it seems to have exercised, upon his attitude towards life and in his personal relations with his friends, a morbid influence which lasted for the remainder of his days. The brighter side of these years is to be seen in the record of his continued work. How great that record is, may be gathered from the tale of his published work.* It includes over 150 memoirs, many of them of considerable length, and six volumes. Reference has already been made to his three-volume treatise on groups of transformations. In a couple of instances, his lectures in amplification and elucidation of portions of his theory were edited and published in volume form by his pupil, Scheffers, whose help is gratefully acknowledged: one of these relates to differential equations that admit of known infinitesimal transformations; the other to continuous groups.

Two other works were promised by him. One of these, to be written in co-operation with Engel, was to deal with the theory of infinite continuous groups and the application of the general group-theory to the integration of differential equations: this work has not appeared. The other, to be written in co-operation with Scheffers, was to be devoted to a systematic exposition of his geometrical investigations; the first volume has appeared under the title 'Geometrie der Berührungstransformationen.'

As his fame grew, placing him in the forefront of the mathematicians of his day, a strong desire was felt by his fellow-countrymen that he should return to Norway, and that some professorship of exceptional dignity should be created expressly for him in Christiania. Such a post was made for him about 1896; but he only returned to his native country to occupy it in September, 1898. The desire of his fellow-countrymen was thus gratified honourably for Lie, but unhappily too late to be effective. His broken health forbade any long tenure of a chair in which, as had been hoped, he would be able to continue his mathematical researches. He was almost a dying man on the day of his return; he lingered through part of the winter; such little strength as was left was undermined by pernicious anæmia; and he passed away on the 18th of February, 1899.

* A full bibliography is given by Engel in the article already quoted in 'Bibliotheca Mathematica,' 3rd ser., vol. 1; see pp. 174—204.

Whatever be any prophetic estimate now made as to the position which the future will assign to Lie among the great mathematicians, his contemporaries and immediate survivors would agree in regarding him as one of the most conspicuous, independent, and original workers in his generation.

A. R. F.

Sir WILLIAM ROBERTS. 1830–1899.

William Roberts was born at Bodedern, Anglesea, on March 18, 1830. He was the youngest son of Mr. David Roberts, of Mynydd-y-gof, and of Sarah, daughter of Mr. John Foulkes, of Machynlleth, Montgomeryshire. Mr. David Roberts farmed his own land in Anglesea, and in addition practised as a surgeon in the neighbourhood, where indeed he was the only medical man. Both of Sir William Roberts's parents lived to a great age, and some of his elder brothers settled in Manchester, where they achieved distinction, and one of them, Alderman J. Foulkes Roberts, was Lord Mayor of Manchester in 1897. William Roberts received his early education in Manchester, subsequently he went to Mill Hill School, and he entered University College, London, as a medical student in 1849. Walsh, Garrod, Jenner, Quain, were amongst his teachers at this period, and Roberts came early under the influence of Sharpey, and the interest which he maintained throughout life in physiological problems was probably aroused by the special influence of this teacher. Roberts had a distinguished career as a student at University College, and he graduated as a B.A. in the University of London in 1851, and took the degree of M.D. in 1854. After completing his studies in London, he studied for some months at Paris and also at Bonn and Berlin. In 1854 he was appointed house surgeon to the Manchester Royal Infirmary, and soon afterwards, when 25 years of age, he was elected, in July, 1855, without opposition, physician to the Royal Infirmary and lecturer on anatomy and physiology in the school of medicine. Subsequently he became lecturer on pathology, and, in 1863, lecturer on the principles and practice of medicine at Owens College. When the Victoria University was established he became Professor of Medicine. In 1883 Dr. W. Roberts resigned his physiciancy at the Royal Infirmary, after serving on the active staff for nearly thirty years. During the whole of this time he was an energetic teacher of clinical medicine, and

the thoroughness and lucidity of his teaching played a considerable part in the successful development of this great provincial school of medicine.

He was admitted a Member of the Royal College of Physicians in 1860, becoming a Fellow in 1865. In 1866 he was Gulstonian Lecturer, and chose as the subject of his lectures "The Use of Solvents in the Treatment of Urinary Calculi and Gout," a subject which interested him throughout his life, and to which he returned in the Croonian Lectures delivered before the College of Physicians in 1892. He was Lumleian Lecturer in 1880, and served on the Council in 1882, 1883, and 1884. He was Censor in 1889 and 1890, Croonian Lecturer in 1892, and Harveian Orator in 1897. In 1877 William Roberts was elected a Fellow of the Royal Society, and he served on the Council of the Society in 1890 and 1891. In 1885 he received the honour of knighthood, and a few years afterwards, in 1889, he removed from Manchester to London, chiefly to obtain more leisure from the calls of a large consulting practice. In 1892 he was appointed a Fellow of the University of London, and subsequently, in 1897, he became the Chairman of the Brown Committee, and he also represented the University of London on the General Medical Council from 1896 till his death. He took great interest in the question of the provision of adequate university teaching in London, and in 1898 he was appointed a member of the Statutory Commission dealing with this question. In 1893 he was appointed the medical member of the Opium Commission, and the Report on the medical aspect of the use of opium was drawn up by him. His cautious mind and freedom from bias rendered him peculiarly suitable for forming a sound and correct opinion on such a hotly contested question. During his stay in India he collected information on the use of anarcotine, one of the alkaloids of opium, and he subsequently drew attention to the uses of this body as an antiperiodic. He held the view that one of the main beneficial uses of opium in such a country as India was dependent upon its being a prophylactic (thanks to the anarcotine it contained) against some of the malarial fevers of the country.

Throughout his life Sir William Roberts was actively engaged in investigating many problems connected with the scientific side of his profession. Both in Manchester and in London he had a laboratory in his house, and notwithstanding the calls of practice he found time to pursue in this laboratory the various investigations the results of which were communicated to this and to other societies. As a young man, in 1858, before he had embarked on the special line of investigation with which most of his subsequent work dealt, he wrote a remarkable essay on Wasting Palsy. This work was noteworthy in that it was not only the first systematic account of the malady in our language, but also as showing the keen clinical instinct of the author, since the types recog-

nised by him have been shown by modern research to belong to distinct and separate groups. Soon after writing this, however, Roberts began the series of chemical investigations on the urine with which his name is more especially associated, and a few years later, *i.e.*, in 1865, he issued the first edition of his well-known work on Urinary and Renal Diseases. This work was a great deal more than a text-book dealing with a certain class of disease; it contained much original matter, the results of the observations carried on in his laboratory, and more especially such questions as the daily variations in the reaction of the urine, the influence of food on the reaction, the estimation of sugar in diabetic urine by the loss of density after fermentation, were largely treated in the light of his own work. The last question was one that interested him throughout his life, and even during the last few weeks of his life, when prostrated by grave disease, he was still engaged in perfecting yet another method of determining quantitatively the amount of sugar by fermentation. In addition to devising new tests for the detection and estimation of sugar and proteids in the urine, Roberts's principal work about this time was the recognition and full description of the symptoms that ensue as a result of calculous suppression, and this chapter in subsequent editions of his book was one of the most important contributions to our knowledge of the effects of suppression of urine.

During the next few years, although still pursuing similar work, Roberts attacked the then vexed question of spontaneous generation, and carried out a long series of experiments, the main results of which were embodied in a paper in the 'Philosophical Transactions' for 1874, and his results are in accordance with the views of the present day. He had previously, in 1863, communicated a paper to the 'Proceedings' on the "Histology of Blood Corpuscles," and in it devised and described methods which were used for thirty years in the routine instruction of students. In 1879 Roberts began a series of investigations on digestive ferments and the artificial digestion of various foods. Many of his results were communicated to this Society in the 'Proceedings' for 1879 and 1881. Sir William Roberts's work on digestion not only added to our knowledge of the action of the digestive ferments, but the practical outcome of this work was very great in affording valuable means for feeding the sick in many diseases, and the very large number of digested and partially digested foods at present available is chiefly due to his work on the subject.

Subsequently to his removal to London in 1889, he carried out a long series of observations on the relationship of uric acid to gravel and to gout. He added considerably to our knowledge of the pathology of these diseases by showing the different decompositions that the quadriurates underwent under different circumstances, liberating now uric acid, now a biurate, &c.

Sir William Roberts's record of work shows well what a busy physician can do in the way of accurate work in the scanty leisure afforded him in the intervals of practice, and all his work, whether chemical or histological, was characterised by the same scrupulous accuracy and neatness. It is probable that few, if any, of his statements of fact will require emendation, although doubtless some of the views founded on them may alter, and indeed have altered, with the lapse of years.

Sir William Roberts married in 1869 Elizabeth, daughter of Mr. Richard Johnson. This lady died in 1874, leaving as issue one son, who died in 1893. Sir William Roberts suffered severely from influenza in 1897, and in the autumn of 1898 symptoms of a more serious illness appeared, and the malady proved fatal on April 16, 1899. Sir William Roberts was buried at Llanymawddwy, Merionethshire, the village near his country residence, Bryn.

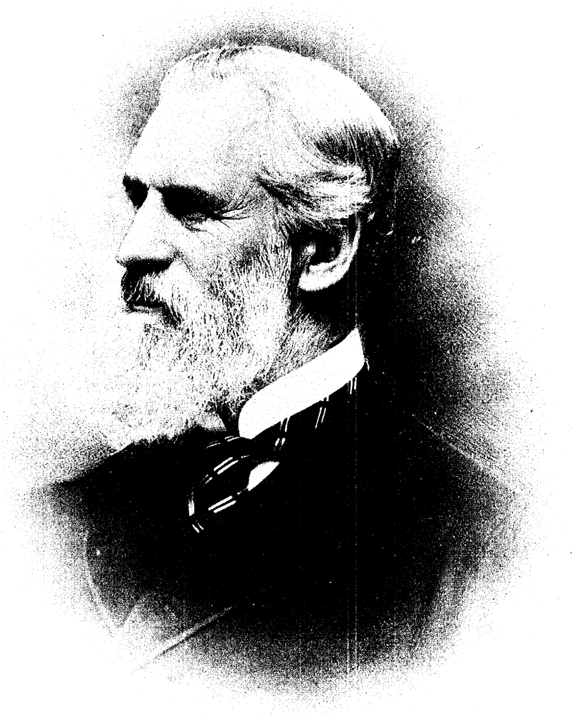
J. R. B.

Sir WILLIAM FLOWER. 1831-1899.

William Henry Flower was the second son of the late Edward Fordham Flower, Esq., J.P., of The Hill, Stratford-on-Avon, being born on the 30th November, 1831. The fine erect figure of his father, also inherited by the son, was familiar in the Park when he was over the threescore and ten, and he was also widely known for his philanthropy, and for his indefatigable efforts to abolish the bearing rein of carriage horses; indeed his interest in the lower animals dated from his early experiences with his father in the American backwoods.

William Flower was educated chiefly at private schools, and from boyhood developed a taste for collecting and arranging objects of natural history. This led to his choosing the medical profession, the only one indeed that then and for many years later formed a sphere for such tendencies in those devoid of private fortunes. Entering University College, London, he had a distinguished career, gaining the gold medal in Anatomy and Physiology, and the silver medal in Zoology and Comparative Anatomy, the gold medal in the latter class having been won by Joseph Lister, lately the distinguished President of the Royal Society. He graduated as M.B. of the University of London in 1851, and became a member of the Royal College of Surgeons. He extended his experiences after graduation, by a tour through Holland and Germany in 1851, and through France and the north of Spain in 1853, bringing home, as usual, many sketches in pencil and sepia.

Life as a young practitioner in London did not long continue, for in 1854 he joined the Medical Department of the Army and proceeded to the Crimea as Assistant-Surgeon in the 63rd Regiment, thus seeing service on land as his friend and predecessor in the Hunterian Chair (Professor Huxley) had seen service afloat. Many and varied were Sir William's experiences in this great campaign—both in field and hospital, for he was present at the battles of Alma, Inkerman, and Balaclava, as well as at the capture of Sebastopol, receiving the medal and four clasps, as well as the Turkish medal for his services. The fatigues, exposure and privations of this campaign severely tested the constitution of the young surgeon, yet in the intervals of duty, and with the scanty materials at his disposal, such as pen and ink and washes of ink and water, he made vivid sketches of his surroundings. Those who remember the terrible sufferings of



W. H. Flower

the army in the Crimean winters, will not be surprised to find these sketches include his own tent blown over in the snow-storm of 14th November, 1854, and another of the prostrate tents of the camp towards the conclusion of the storm. The hospital at Scutari, a large panorama of Constantinople, and many other subjects proved his capacity to wield, with equal skill, both brush and scalpel. While he as a general rule, and with the eye of the anatomist, devoted great attention to form, yet from early days he was no stranger to sketches in water-colour.

His health, however, was seriously affected by his service in the Crimea, and he retired from the Army on his return to London. With the view of practising as a surgeon, he became Assistant-Surgeon, Demonstrator of Anatomy and Curator of the Museum in Middlesex Hospital, posts not uncongenial to the methodical and painstaking comparative anatomist, who utilized his opportunities in preparing his first work, viz: "Diagrams of the Nerves of the Human Body," with six plates, the nerves having the names printed on them, and their distribution being clearly outlined. This work proved very useful to physiologists, students, and medical men. He also contributed an article on "Injuries of the Upper Extremities" to Holme's 'System of Surgery.' Two of his early zoological papers, viz.: "Notes on the Dissection of a Galago," and "On the Posterior Lobes of the Cerebrum of the Quadrumana," also pertain to this period.

There is no doubt that the breathing space thus afforded, allowed him time to collect his energies and gather up a store of valuable information for utilizing subsequently. Moreover, it was during this period of his career that he married in 1858, at the Church of Stone, near her home in Buckinghamshire, Georgiana Rosetta, youngest daughter of the late Admiral W. H. Smyth, K.S.I., D.C.L., F.R.S., who served the Society as Foreign Secretary, and was often on its Council. This step in Flower's history had an important bearing on his future success, for constant contact with such relatives as the distinguished officer just mentioned, with Sir Warrington Smyth, F.R.S., Professor Piazzi Smyth, General Sir Henry Smyth, Rev. Baden-Powell, and others could not but tend to shape the career of the young comparative anatomist. A tour with his wife through Belgium and along the Rhine, made a pleasant holiday at this period.

The bent of his mind, as his friends Professor Huxley, Mr. George Busk and others perceived, was towards Comparative Anatomy, and he soon (1861) received a congenial appointment as Conservator of the Museum of the Royal College of Surgeons, a post rendered vacant by the death of Mr. Queckett, who had devoted much time and labour to microscopical researches in the Museum. Here in the midst of specimens, rendered historical by the labours of John Hunter and Richard Owen, and of new and important specimens added under his guardian-

ship, he produced memoir after memoir, to which allusion will elsewhere be made. The collection itself, under his fostering care attained a perfection and value that have made it famous all over the world, especially in regard to the skeletons and spirit-preparations of rare and unique forms. The patience with which he measured, figured, and described minute differences or salient features in skeletons, or exposed the characters of soft parts by dissection, have rarely been equalled. Moreover, as he generously acknowledged, the unique series of dissections of muscles, blood-vessels, and viscera (mostly human) was designed and largely executed by Professor Pettigrew, according to a process devised by this ingenious anatomist and physiologist. As the President of the Royal Society stated on presenting Sir William with the Royal Medal, "it is very largely due to his incessant and well-directed labours that the Museum of the Royal College of Surgeons at present contains the most complete, the best ordered, and the most accessible collection of materials for the study of vertebrate structures extant." These labours give to his work on Comparative Osteology an accuracy and thoroughness all its own.

Besides his more strictly scientific work, he about this time began the series of popular lectures by which he enlisted the sympathies of a wider audience, and extended general information on interesting and important subjects. One of his earlier lectures in this department brought under review the condition of the human foot and its coverings in the various races of men.

The retirement of his friend, Professor Huxley, from the Hunterian Professorship of Comparative Anatomy and Physiology in the College of Surgeons was followed by his own appointment, and he held this office from 1870 to 1884. His Introductory Lecture, in February 1870, brought in a memorable way before his hearers such topics as type or plan, transmutation of species and organic evolution, and he prefaced his remarks by explaining that as the main part of his knowledge was gained by constant contact with the noble collections in the Museum, so he intended to act as the mouth-piece of the specimens and endeavour to convey to his audience what they had taught him, and this and his subsequent courses more than justified his method. His comparison of the foot of the Koala and that of the Kangaroo, the teeth of the Thylacine and that of the Dog afforded his audience an excellent illustration of the developmental theory as propounded by Darwin and Wallace. His lectures were published in 1870. In the following course (1871) he gave eighteen lectures on the structure, functions and modifications of the teeth of mammals from man to the monotremes. The true teeth of Ornithorhynchus, however, were not then known, and it was reserved for Professor Poulton at a later period to demonstrate them. These courses of lectures often revealed the nature of his studies, *e.g.*, those of 1877 being "On the Relations

of Extinct to Existing Mammalia," while those of 1880 were on the "Comparative Anatomy of Man, especially skulls from Viti Levu and Vanua Levu Islands, compared with the Tongans and Samoans." Few have any idea of the great amount of labour such courses involve, yet no one would have imagined this from the ever-ready and earnest efforts of the lecturer to give to others that knowledge, which it had been a pleasure to gain amidst the treasures of the Museum.

On his appointment to the Museum of the College of Surgeons, Sir William retired from practice, yet, though his subsequent career was devoted to science, he never lost touch with or interest in his old profession. This loyalty has been one of the most characteristic features of the scientific followers of medicine from early times, and is familiar to us in the lives of John Hunter, John Goodsir, Richard Owen, Thomas Huxley, B. W. Carpenter, George Busk, George Allman, John Hutton Balfour, George Johnston, Strethill Wright, and many others. Broader views are engrafted on medicine, and science is strengthened by the inclusion of such men in both, and it is well if this tradition is cherished in the present and in the future.

No comparative anatomist in recent times has more devotedly or with greater ability and accuracy studied the mammals; indeed the majority of his contributions to science, many of them of a very elaborate character, deal with this subject. Moreover, in every instance he has enlarged our knowledge, not only of the species, but, by acute and comprehensive views, he has extended that of the group; and since the range of his contributions in this department passes, with a few exceptions, from the Monotremes to the Primates, his influence in moulding the present literature of the subject has been immense. Amongst his earlier contributions, after entering on duty at the College of Surgeons Museum, are papers on the anatomy of the Primates—including both old and new world forms. His researches on the brain of the higher apes formed an important feature in the discussions which took place between Owen and Huxley in regard to the posterior lobe of the brain, the posterior cornu, and the hippocamus minor being or not being diagnostic of separation between man and the monkeys.

Owen, at the Cambridge meeting of the British Association in 1862, maintained—from casts of the human brain in spirit, and from a cast of the interior of the gorilla's skull—that in man the posterior lobes of the brain overlapped the cerebellum, whereas in the gorilla they did not; that these characters were constant, and therefore that he placed man with his overlapping posterior lobes, the existence of a posterior cornu in the lateral ventricle, and the presence of a hippocamus minor in the posterior cornu—under the special division Archencephala. Moreover, he grouped with these features the distinctive character of

the foot of man, and showed how it differed from that of the ape and gorilla.

Flower's accurate investigations in this field gave rise to a valuable contribution "On the Posterior Lobes of the Cerebrum in the Quadrumana," and enabled Huxley to substantiate his position that these structures, instead of being the attributes of man, are precisely the most marked cerebral characters common to man with the apes. Huxley also demonstrated that the differences between the foot of man and that of the higher apes were of the same order, and only slightly different in degree from those which separated one ape from another.

Early in the sixties Flower's papers on the neck vertebræ of the Sea cows, and on the Lesser Fin-whale stranded on the coast of Norfolk, seem to have aroused within him a latent charm for cetacean structure —a charm which held him to his last working moment. Hence the prominence in his subsequent labours of memoirs dealing with the subject, *e.g.*, "The Skeletons of Whales in Holland and Belgium," "A Tasmanian Grampus," "*Pseudorca meridionalis*," "Sibbald's Rorqual," "The Pevensey Fin-whale," "Identity of Fin-whales Carolinæ and Sibbaldii," "Four Specimens of the Common Fin-whale," "Osteology of the Cachalot," "On the Fin-whale of Langston Harbour," "On a Sub-Fossil Whale in Cornwall," "Ziphoid Whales," "Skeleton of the Chinese White Dolphin," "On Risso's Dolphin," "On Recent Ziphoid Whales," &c. In 1866 he also advanced his favourite study by translating and editing for the Ray Society the classical memoirs of Professors Eschricht, Reinhardt, and Lilljeborg on the Whales, and adding many important notes and an illustrated appendix of his own. Other contributions on the cetaceans and their allies included "On the Skull of Xiphodon," "On Dr. Haast's Ziphius and Mesoplodon," "On a Collection of Seals and Cetaceans from Kerguelen," "On the Common Dolphins," "On the Cranium of Hyperoodon," "On a Whale of the Genus Hyperoodon," "On the Characters of the Delphinidæ," "On a Species of Rudolphi's Rorqual taken on the Essex Coast," "On the External Characters of Two Species of British Dolphins." No one in our country, except Sir William Turner, has laboured more persistently and with such conspicuous success at this interesting and important group, and no one had a clearer grasp of its affinities. Foreign museums were in some cases more than once ransacked for information such as those of Leiden, Utrecht, Brussels, Louvain, Paris, Heidelberg, Berlin, Dresden, Nuremberg, Strassburg, besides those of Norway and Italy.

While thus engaged in his laborious observations amongst the skeletons and other parts of whales, the museums of Britain and the Continent were in some cases more than once ransacked for information, which he had accumulated in two fascinating lectures, the one "On Whales and Whale Fisheries," at the Royal Colonial Institute, and the

other, "Whales, Past and Present, and their Probable Origin," at the Royal Institution. In concluding the latter he points out that the difficulty of deriving the whales from the primitive and probably omnivorous Ungulates is not great, since the aquatic branch might easily have gradually become more and more piscivorous, the purely terrestrial members more conclusively graminivorous.

The foregoing great labours of his life consistently culminated in the magnificent series of whales it was one of his last duties to arrange and exhibit, with remarkable ingenuity, in the hall which he had secured for them in the British Museum (Natural History). While the skeleton can be studied from one side, the coloured outline of the body, in papier-mâché is placed on the other, and numerous drawings in water-colour (many by one of his daughters) still further enable the visitor to grasp the form and structure of these gigantic denizens of the deep, or of remote rivers. Here ranged, side by side, are giant finners and small porpoises, narwals and killers, the toothed whales having their heads one way, the whalebone whales having theirs in the opposite direction. No more fitting memorial of the skilful hand of the leading European authority on the subject could be found than this marvellous and unique display of forms—rare it is true—but replete with the most interesting habits and, in many cases, remarkable intelligence.

For some years after entering on his work at the College Museum, the brains of mammals formed a favourite study, and, besides the paper already mentioned, there were others "On the Brain of the Siamang," "On the Brain of the Javan Loris," "The Brain of Echidna," "The Brain of the Howling Monkey," "Cerebral Commissures in Marsupials and Monotremes," the latter in reply to Sir R. Owen's paper on zoological names of characteristic parts and homological interpretations of their modifications and beginnings—especially in reference to the connecting fibres of the brain.

Amongst the papers which had an important influence in zoology was that in 1867, "On the Development and Succession of Teeth in the Marsupials." He showed that there was but a single tooth (hindmost premolar) on each side of each jaw with a vertical predecessor or undoubted milk-tooth. In the kangaroos, opossums, and thylacines this single tooth is homologous with that most persistent in typical diphyodonts, viz., the posterior milk molar—replaced by the posterior premolar. It is interesting that he interpreted the teeth in front of the latter as corresponding to the permanent set, an opinion the recent discovery of rudimentary milk-teeth substantiates. In the same group he discovered that the extinct *Thylacoleo carnifex* of Owen was not a carnivore, but, probably, a herbivorous marsupial, most nearly allied to the rat-kangaroos, yet having special features of its own in the diminished number of true molars, the great size of the trenchant anterior

premolar, and the rudimentary canines. These two papers would alone have made a reputation, and rewarded his patient and persevering labours in the osteological collections of the Museum.

About this time (1870) he published his well-known "Osteology of Mammalia," which has been so useful to every student of the subject, and has done more than any other treatise to give an intelligent grasp of human anatomy; the skull, spine, pelvis, and other regions are treated separately, the typical form being given first, and then the special peculiarities. He further added a new bone (the tympano-hyal) to the well-worn subject of human anatomy. The success of this accurate and well-arranged work was great. A second edition was issued in November, 1876, many new features being interpolated, such as those relating to the chevrotain and the muntjac. A third edition followed, in 1886, with 134 illustrations, and a table of the vertebræ of 350 mammals. Dr. Hans Gadow, of Cambridge, assisted him with this edition.

His busy brain and fertile pen produced other important memoirs, the results of some being incorporated in the work just mentioned. These included "The Development and Succession of Teeth in the Armadillos," "On the Anatomy of Proteles," together with memoirs "On the Connection of the Hyoid Arch with the Cranium," "On the Pelvic and Shoulder Girdles," "On the Anatomy of *Ælurus*," "On the Carpus of the Dog, and of the Sloths," "On the Ringed or Marbled Seal and the Spotted Paradoxure," "The Lobes of the Liver in Mammals," "Halitherium," "Extinct Lemurina," "*Hyœnarctos*," "Skull of Rhinoceros," "On the Elephant Seal," and "On the Value of the Characters of the Base of the Cranium in Carnivora." The latter paper showed that in the three great groups of the carnivores a gradational series is formed by the tympanic bulla and the character of the septum so that there were structural grounds even on this head alone for the old groups of cats, dogs, and bears. His contributions to the structure of the mammalia, indeed, range almost over the entire field from monotremes to man, and in reading the long list of important memoirs one marvels at the unflagging zeal and industry of the man and the penetration and sound deduction of the philosopher. His paper on the arrangement of the orders and families of existing mammalia following his contribution to the 'Encyclopædia Britannica' was the prelude to his standard work, along with Mr. Lydekker, on the Mammalia. Again, few popular works can surpass—in the clear and comprehensive grasp of the subject, in felicity of expression, accuracy of detail, and well-chosen illustrations—his treatise on the Horse (1891) which he truly makes a study in Natural History.

Besides his memoirs on the mammalia, Sir William Flower extended his studies to the birds, especially during his earlier years. Thus his contributions embrace an account of the "Gizzard of the Nicobar

Pigeon," the "Gular Pouch of the Great Bustard," the "Skeleton of the Australian Cassowary," and "On the Substance ejected from the Stomach of a Hornbill."

Though he did not illustrate with his own hand many of his papers, Sir William was an artist of considerable ability. His beautiful sketches in water-colour during the Crimean campaign were the prelude to a much more extensive series made jointly by Lady Flower and himself during his enforced holiday in Egypt in 1873-4. These represent the most varied scenes on their route, and exhibit the accurate touch of the artistic naturalist, especially in the portraiture of animal and tree, and in the skilful treatment of the landscape. That he could, if time had permitted, have ably illustrated his own memoirs is proved by a glance at his careful drawings of the brains of the apes in the 'Philosophical Transactions.'

In no department was Sir William's medical training of greater value than in his studies at home and abroad in anthropology. These he pursued with patient enthusiasm in the Museum and elsewhere for years, accurately measuring and comparing thousands of specimens. As a result, there appeared in June, 1880, his important 'Catalogue of Specimens illustrating the Osteology and Development of Vertebrate Animals —recent and extinct. Part I, Man.' In this laborious and accurate work, he dealt with the general osteology of man, then with his dentition, and thirdly with the special osteology of man, that is, those variations which have become so constant as to give distinctive characters to the several races. His important remarks on the measurements of skulls, and his tables for calculating cranial indices, nasal, orbital, and alveolar indices, all bore the imprint of scrupulous exactitude. He used mustard seed and Mr. Busk's choremeter in estimating cubical capacities. Before the publication of this work he had given various lectures and addresses on the same subject, such as "The Aborigines of Tasmania," "The Native Races of the Pacific," at the Royal Institution; "The Races of Men" in November, 1878, at Glasgow. Subsequently he further dealt with the subject in his addresses as President of the Anthropological Section of the British Association in 1881, 1884, and 1894; in his address "On the Classification of the Varieties of the Human Species," at the Anniversary Meeting of the Anthropological Institute in 1885, "On the Pygmy Races of Men," natives (and it may be early inhabitants) of the west of Lake Albert Nyanza, and only a little over 4 feet in height, experts with the bow and arrow and great elephant hunters, at the Royal Institution; and on "Fashion in Deformity" in the same place. His papers on the "Size of Teeth as a character of Race," "On the Osteology of the Andaman Islanders," "On the Malicolese," and "On the Natives of the Fiji," likewise contain important contributions to the subject. The same may be said of his comparatively recent paper

(1895) "On the Aboriginal Inhabitants of Jamaica," his conclusions being that the skulls present decided characters pertaining to the American type. His labours in this field are of great value, and some of his papers treat of races that are disappearing or that have disappeared, the materials for the study of which he was fortunate in obtaining. Sir William was thoroughly interested in this field, and the vigour with which he delivered the opening address to the Anthropological Section of the British Association at Oxford (1894) must have struck all who heard it.

His tenure of office, viz., twenty-two years, as Conservator of the Museum of the Royal College of Surgeons, was a splendid record of original and laborious work, of great administrative capacity, and of unvarying courtesy to visitors. The Museum was most popular under his management. There, amidst the almost unrivalled collections, the tall, fair-haired and earnest worker was daily to be found, minutely studying, comparing and measuring, or giving directions for the extension, arrangement, and classification of the varied and valuable contents. From a scientific point of view no post could have been better adapted for the man or the man for the post. With many and varied lines of study lying conveniently around him, in the quietude of an office less conspicuous and exacting than that of the British Museum, in the full vigour of manhood, and in the midst of sympathetic seniors, friends, and assistants, it can well be imagined that Sir William's powers attained great development, and that, perhaps, he never felt so full of happiness and satisfaction with his original work. It could not well be otherwise. His conscientious devotion to duty, his remarkable skill in devising methods of mounting, his artistic eye, his tact with subordinates, and the esteem in which he was held by zoologists and comparative anatomists at home and abroad, give a clue to his subsequent career, and show the training of one of the most accomplished and courtly comparative anatomists our country has produced.

Of his long-continued and conspicuous labours in the College Museum little further need be said than to make a brief extract from the minute of the Council on the 13th March, 1884:—

"Moved by Sir James Paget, seconded by Mr. Erichsen, and resolved unanimously:—'That the Council hereby desire to express to Mr. William Henry Flower their deep regret at his resignation of the office of Conservator of the Museum of the College. That they thank him for the admirable care, judgment, and zeal with which for twenty-two years he has fulfilled the various and responsible duties of that office, that they are glad to acknowledge that the great increase of the Museum during those years has been very largely due to his exertions, and to the influence which he has exercised, not only on all who have worked with him, but amongst all who have been desirous to promote

the progress of anatomical science. That they know that, whilst he has increased the value and utility of the Museum by enlarging it, by preserving it in perfect order, and by facilitating the study of its contents, he also maintained the scientific repute of the College by the numerous works which have gained for him a distinguished position amongst the naturalists and biologists of the present time.'"

Professor Flower shortly afterwards was elected a Trustee of the Hunterian Collection of the College.

While in the midst of his labours in the Museum of the Royal College of Surgeons, he was, in 1879, unanimously elected to the important and prominent, though honorary, office of President of the Zoological Society, a post which he held till his death. Under his presidency the Society had an unbroken career of scientific success, and largely through his influence and that of the indefatigable and able secretary of the Society, the Gardens constantly received rare and valuable specimens from every quarter of the globe. The financial depression in the affairs of the Society which ensued in the early eighties was skilfully combated by his patient sagacity and great administrative powers, and long before his death the Society reached a stage of prosperity which had rarely been equalled in its history. Many of his important scientific contributions had been made to the Zoological Society before his election as President, and many others were communicated subsequently, so that with his annual addresses, his experienced remarks from the chair at the ordinary meetings, his addresses on special occasions, for instance, in the Jubilee year, he took a conspicuous share in the work of the Society. By nature and culture he made an ideal President of such a body. Many a young zoologist, embarrassed during his communications to the meetings, has been encouraged and aided by the kindly help of the President, whose tact and resource on these occasions were always reliable. Here he also entertained great social gatherings of the Fellows, and their friends, as, for instance, in the garden party in the Zoological Gardens in June, 1887, functions in which he was so ably seconded by Lady Flower, and which rendered these and similar social efforts so successful. The experience gained in similar social gatherings (such as receptions) at the Museum of the Royal College of Surgeons thus proved of value in other spheres. A distinguished man of science who could at a single reception at the College Museum interest 800 guests could not be otherwise than a power in popularising the department. This indeed was a notable feature in Sir William's career, and one that gave his public life a special character. He was equally at home in taking Royal Personages through the galleries of the Museum as in receiving bands of working men for the same purpose, and this ease was largely due to the fact that both the one and the other had implicit confidence in him.

On the resignation of Sir Richard Owen, whose long-continued and conspicuous labours had rendered British Comparative Anatomy esteemed everywhere, there was but one man whose life and work, and whose fame, pointed him out as Owen's successor, viz., Sir William Flower, and, accordingly, in 1884, he was appointed Director of the great Museum of Natural History at South Kensington. Thus slowly but surely the goal was reached by him who as a boy treasured and arranged a few zoological specimens that fortune sent in his way, and who in manhood left a splendid record of his able administration and artistic methods at the Museum of the Royal College of Surgeons. His long experience and natural gifts thus gave to the National Museum one of the most accomplished, courtly, and wise, administrators of the age; a man not only distinguished as an original investigator, but one whose high tone and affability won the hearts of officials as well as those of the public.

The great building in which he was henceforth to labour was the product of the genius of his predecessor, to whom he ever paid a just tribute for his gigantic labours, yet early in its history the keen eye of Sir William, while admitting the beauty of form, proportion, colour and material, looked in vain for administrative offices, libraries, laboratories, lecture-rooms, and, above all, accommodation for the vast and ever increasing collections necessary for scientific research. Some of these defects have, it is true, been remedied, but the result falls far short of the ideal which this Prince of Museum Directors* evolved from his unique experiences. However this may have been, he set himself with characteristic ability and energy to labour in his new sphere, and with such effect that the fame of the great Museum and its Director became cosmopolitan. The entrance-hall and neighbouring galleries soon teemed with unique groups, which, even to the popular mind, afforded an insight into the variations of animals, and their adaptation to the colour of their surroundings. Thus in one case were shown the variations of the canary, in another the remarkable varieties of the pigeon in domestication—jacobins, pouters, fantails, tumblers, carriers, &c.—all developed from the accompanying rock-dove. In a third the apparently endless sexual variations of the ruff, no two being alike. Illustrations of albinism, such as white sparrows, crows and blackbirds and of the white winter dress of the mountain hare and the ptarmigan, and of melanism made even the most casual visitor ponder over the information placed before him in the carefully prepared labels. In like manner the brown hue of sand-frequenting mammals and

* This was the compliment Professor Virchow, of Berlin, paid him, when one who was accompanying him round the Museum of the College of Surgeons, expressed surprise at the perfect arrangements of the collection: "Why should you be surprised," said Virchow, "when the Museum is under charge of the Prince of Museum Directors, Professor Flower?"

grouse told, by aid of the labels, its own tale. In the "bays" of the hall the splendid Index-Collection enabled students to comprehend the leading features of the various groups of animals in a manner never before seen. The exquisite dissections and artistic method of exhibition of these specimens alone would have made Sir William's term of office noteworthy. His young assistants—amongst whom the late Mr. Wray was the pioneer, and Dr. Ridewood his successor—vied with each other in the excellence and beauty of these preparations—made under the experienced direction of their chief. To zoologists they are ever fascinating and instructive. The skilful methods adopted for illustrating the various modifications and succession of teeth, of the structure of limbs, of claws, beaks, and wings, from the most rudimentary organs of the penguin to the great expanse of the frigate-bird and albatross, and of the colour, size, and number of eggs, cannot be surpassed. It was this methodical and accurate system of working that led Mr. Wray to ascertain the curious fact that the fifth cubital quill is absent in certain groups of birds, hence the term "aquintocubitalism." In the invertebrates, such as the crustaceans and mollusks, the same thorough methods were adopted, so that the Index-Collection was a marvel of information. The great halls of the mammals, birds, reptiles, fishes and other forms, such as the corals, under his fostering care, assumed remarkable order and neatness, and new and rare specimens were rapidly accumulated. There was a striking improvement in the classification and taxidermy of the mammals, in the mode of mounting on stands, and in the acquisition of the larger and rarer African and Indian forms. In the collection of birds, the polished sycamore stands gradually disappeared, and, instead, a dull surface of a good cigar-brown was substituted by staining the wood. This was the result of careful experiment under the experienced eye and refined taste of the Director himself, and a suggestion from the late President of the Royal Academy, Lord Leighton. Every effort was made to give the specimens natural postures and natural surroundings. Thus, for example, the tree on which the woodpecker was at work was cut down, the foliage modelled in wax, and all the surroundings carefully kept. Hovering birds were suspended by fine wire or thread. Birds making nests in holes, such as the Manx shearwater, sand-martin, and kingfishers, either had the actual parts or a model of these beside them, just as the nests of the gannets and guillemots on the Bass Rock were shown with their natural environment. The birds, moreover, were re-classified. In the same way Lord Walsingham's splendid collection of British butterflies and moths with their caterpillars and food-plants illustrated the life-history and often mimicry of this interesting group. He was busy with the life-histories of other important groups just before his retirement, *e.g.*, the food-fishes, and he

would have illustrated these in the same complete and instructive manner.

A general guide to the Museum under his auspices was published in 1887.

While thus maintaining the high scientific reputation of the Great National Museum, he continued to popularise the institution and science by taking parties of working men round the Museum on Sundays, and occasionally a distinguished visitor, like Dr. Nansen, would also join the group. Nor was he less attentive to Members of the Royal Family, or to distinguished statesmen, like Mr. Gladstone, who honoured the Museum with their presence. Foreign rulers, like the Queen of Holland, the Prince of Naples, the Emperor Frederick of Germany, and the King of Siam, were also interested in the collection, so that the popularity and welfare of the Museum were greatly extended by the Director's tact and urbanity. Formerly, he had taken a leading part in interesting the Prince of Wales, who was present at Sir Jas. Paget's Hunterian Oration in 1877, in the Museum of the College of Surgeons, and in arranging for an exhibition of the Prince's Indian Hunting Trophies at the Zoological Society shortly afterwards, so in his new sphere Royal and other powerful influences were utilized for the improvement and popularising of the collection. Military and Naval Expeditions, Exploring Expeditions, all contributed their quota to the National Museum. One of his last collections of this kind was Emin Pasha's from Central Africa.

The Trustees, when Sir William reached the age limit of the Civil Service, extended his period of office by three years, but in July, 1898, failing health compelled him to resign. A Minute of the Standing Committee of the Trustees, signed by Lord Dillon, expressed their profound regret at his retirement, and paid him every compliment possible as the worthy successor of Sir Richard Owen, and as one who had organised a Museum of Natural History so pre-eminent amongst the Museums of the civilised world. Thus ended his thirty-six years of Museum work.

The energies of Sir William, while thus more than fully occupied, were yet often taxed by the organisation or the ceremonies connected with the opening of museums in the provinces, and, unmindful of self, he often expended much time and strength in their interests. His addresses in connection with the "Booth Museum at Brighton," and "Local Museums" at Perth, are examples. Besides, in the able and eloquent address which he delivered as President of the British Association at Newcastle, he dealt in a comprehensive manner with "Museum Organisation." "Modern Museums," again, formed the theme of his address to the London Meeting of the Museums' Association, of which he was President.

"School Museums" were specially treated in an article in 'Nature,'

and "Boys' Museums" in 'Chambers' Journal.' Lastly, "The Museum of the Royal College of Surgeons of England" formed the subject of a most interesting address to the Anatomical Section of the Medical Congress. He had besides the distinction of opening the great Marine Laboratory at Plymouth, and he performed this duty in a manner worthy of the occasion and himself. Moreover, at a time when his health rendered such a journey inadvisable, he generously travelled northwards at the end of October, 1896, to aid Lord Reay in opening the Gatty Marine Laboratory at St. Andrews.

Few scientific men of position have exerted themselves more continuously to popularise science than Sir William. Some of his earlier lectures were to Mutual Improvement Associations and non-scientific bodies, while the majority were to mixed audiences, or to more or less scientific ones. Some of his lectures at the Zoological Gardens, and in connection with the Zoological Society, contained the result of much patient research, such as those "On Sloths and Ant-eaters," and "Dolphins," and the same may be said of those "On Horses, Past and Present," "Cattle, Past and Present," and "Fins, Wings, and Hands," at the London Institution; "On Wings of Birds," "On the Horse," and "On Seals," at the Royal Institution. In all these his fluent delivery and fine presence, as well as his thorough acquaintance with the subject, carried both instruction and conviction to his audience.

His addresses, like his lectures, covered a wide area, and his energies must often have been severely taxed in the performance of so many engagements, while his busy brain was otherwise at work. His more general addresses included a loyal tribute to Her Majesty on Jubilee day at the Zoological Society in June, 1887, one when presenting the prizes to the students of University College, an address at the Church Congress, opening address to the First Chelsea Industrial Exhibition, 1887, a speech at the Civil Service Dinner of 1890, an address at the Burial Reform Association, others at the Shakespeare School on speech-day, the Church of England Society for the Promotion of Kindness to Animals, and to the Hammersmith School for Girls. That to the Church Congress, in 1883, was a notable one, since it treated of the meaning of evolution and the kind of evidence on which it rests. "Can it be of real consequence," he asks, "at the present time, either to our faith or our practice, whether the first man had such an extremely low beginning as the dust of the earth, or whether he was formed through the intervention of various stages of animal life? The reign of order and law in the government of the world has been so far admitted, that all these questions have literally become questions of a little more or a little less order and law." He further pointed out that the evidences of the Divine Government of the world and of the Christian faith, have been sufficient for us, notwithstanding our knowledge that the individual and the race were created according to law. His eloquent and manly

address must have had an important influence in placing the subject before the assembled clergy in a reasonable light. The range of his knowledge was equal to the calls made upon it, and he descanted with equal facility on burial in sand, in urging the claims of kindness to animals, or in strongly upholding his father's view as to the cruelty of the bearing-rein in horses.

His other addresses were stored with information or contained graceful tributes to the memory of deceased friends, like Darwin, Huxley, and Rolleston, as well as to other distinguished naturalists, such as Owen. In his address as President of the Department of Anthropology at York, in 1881, he alluded to the difficulties in the scientific investigation of man, the paucity of workers, of libraries, and museums. It must have been gratifying to him to find that within a few years great strides had been made, and that an Anthropological Institute, of which he was President, was devoted to the study of the subject he had done so much to advance by his researches and by his eloquence. At the meeting of the British Association in Aberdeen (1885), he was the foremost zoologist, equally at home in criticising the valuable papers by Sir William Turner and the late Sir John Struthers on the whales, beautiful skeletons of some of which had been prepared for the occasion; or in speaking on the interesting questions raised by Sir John Lubbock (now Lord Avebury) in his address on the dog, as well as taking a kindly interest in the remarks of the whaler, Captain Gray, whose model in wood of a right whale is now in the British Museum, and a woodcut from which illustrates his joint work on the Mammals. He also gave an address at the Loan Collection of Scientific Apparatus at South Kensington.

A life so continuously devoted to the advancement of knowledge, and so productive in its results, was well worthy of the many honours that fell to him. Besides those already mentioned, he was made C.B. in 1887; he received a Royal Medal from the Royal Society in 1882 for his valuable contributions to the morphology and classification of the mammalia and to anthropology. He received the degree of LL.D. from the Universities of Edinburgh, St. Andrews, and Dublin (Trinity College); D.Sc. from Cambridge, and D.C.L. from Durham (1889), and Oxford (1891), the public orator welcoming him as a proof of the proverbial saying attributed to one of the Seven Wise Men of Greece, *ἀρχὴ ἄνδρα δείξει*, and as having passed with ever increasing distinction through a variety of public posts. The Government of the day (1892) made him K.C.B., and he was honoured with the Jubilee Medal from Her Majesty. He was a member of many foreign societies, institutes, and academies, such as the Netherlands, Sweden, Belgium, and France. Moreover, he was the recipient of the Royal Prussian order, "Pour la mérite" from the German Emperor, "the one European decoration," as a distinguished friend wrote in his congratulatory letter, "which an

Englishman may be proud to wear, and bestowed, as I believe it to be, with the sanction of the very few who have already got it. It is the one order which real work, apart from rank and wealth and courtiers' tricks, alone can win." It was truly "the blue ribbon of literary and scientific decorations," as another distinguished friend wrote. Sir William was also appointed in 1881 a trustee of Sir John Soane's Museum.

One side of Sir William's life deserves special notice, viz., his social influence, and the endeavour to popularise the great institutions with which he was officially connected. These influences, developed at the Museum of the College of Surgeons with great success, were brought to bear on a much wider circle in connection with the National Museum and as President of the Zoological Society; and no one was more fitted than he—either for the courtly circle or the large gatherings of working men who flocked on Saturday afternoons to the galleries of the Museum. In all his many and varied social functions in his prominent positions he was ably seconded by one who identified herself with his every engagement, and to whom his last volume of collected addresses is dedicated. A man of wide sympathies: he is found at one time addressing a civil service dinner, at another a volunteer gathering, now descanting on evolution to a church congress, and, again, speaking at a mayoral banquet, a girls' school, or an industrial exhibition. The strain on his physique demanded by these efforts would have been great to an ordinary man, but it must have been serious to one whose main energies were heavily taxed by exhausting scientific work. His powerful constitution was thus slowly but surely sapped, yet to an eager mind and a generous heart, such as his, little heed was paid to himself.

The social side of Sir William's life and his sympathy with the affairs of men were further exemplified in his many communications to the 'Times' and other journals. Some of these were written in the cause of animals, such as that pleading for the bottle-nosed whales which were to be ruthlessly slaughtered as the devourers of food-fishes, or for the protection of birds, as in the appeal to ladies not to wear white heron's or egret's feathers, since the birds were killed when nesting or attending their young. Others dealt with what may be called international zoology, as the Behring Sea question (and he also selected the British naturalist who visited the region). Amongst other zoological subjects were the preparation of anatomical specimens for museums, Emin Pasha's collection, kingfishers' nests, and dwarfs of Central Africa. He also advocated the placing of a statue of Huxley beside that of Owen and Darwin in the entrance hall of the British Museum, so that "Huxley and Owen, often divided in their lives, would come together after death in the most appropriate place and amidst the most appropriate surroundings." He descanted also on subjects so varied as the burial of the dead in slight frames and sandy soil, on Cleopatra's

Needle, on the gardens in Lincoln's Inn Fields, Postal Reform (in pointing out that while we can send a heavy book for a few pence, a heavy letter is costly, and thus he anticipated the arrangement of to-day), on Boehm's monument to Dean Stanley, and on the Cromer waterspout.

In private life no one was more beloved and esteemed. He was in every sense a domestic man, finding the highest joys that life brought him with his family and children. The same courtly bearing and high tone, the same reverence for all that was good, was in private circles mingled with the genial smile, the fascinating account of something interesting or novel, and the respect and deference to others which were part of his upright unselfish nature. Many a young naturalist will gratefully remember the kind encouragement and valued advice he was ever ready to offer, and the stimulus which the sympathetic interest of a leader in the department gave him.

In the busy life of Sir William and in the constant calls on brain and nervous system—strong though these were—there came times when a feeling of lassitude with headache, and spinal uneasiness, if not prostration, showed that the indoor life and the strain of many duties had told with severity both on the central nervous system and the heart. His annual holiday sufficed in many cases to recruit his energies, especially when he visited Scotland and the charming home of his friends, Mr. and Mrs. Drummond, of Megginch. There he met other friends, such as Dean and Lady Augusta Stanley and Colonel Drummond-Hay, of Seggieden, brother of Mr. Drummond. Moreover, he was always interested in the splendid collection of birds made by Colonel Drummond-Hay during his wanderings with the Black Watch, and which is placed in Megginch Castle, while a more recent and exquisite series of birds, like the former, mounted by himself, exists at Seggieden. But at other times a more prolonged absence from persistent work was necessitated. Thus it was that he made a tour with Lady Flower in Egypt during the winter of 1873-74; that he went to Biarritz in 1892.

Sir William had been in failing health for upwards of two years. The symptoms of overwork, causing an affection of the heart, became more pronounced after a journey to Scotland in the end of October, 1896, when he took a prominent part in the opening of the new Gatty Marine Laboratory, St. Andrews. A respite from duty in the beginning of the year 1897 became imperative, and this he took at Marazion, on the south coast of Cornwall. The needful rest, the fresh air, and the charming surroundings gradually restored him to a measure of health, and he returned to the work of the Museum. He spent part of the next winter abroad, but in 1898 he felt his health was no longer to be relied on, and he resigned his post at the British Museum. Last winter he resided at San Remo, returning home in May, 1899. Un-

fortunately a severe attack of pleurisy supervened after reaching London, and he gradually lost strength and peacefully passed away on July 1, in his 68th year.

Tall, fair-haired, and blue-eyed, he had a handsome form as well as a commanding presence, and these natural gifts were combined with a ready and earnest address, so that his appearance on public platforms, such as those of the British Association and the Royal Institution, was always welcome and always popular. In private life he was beloved by his family (which next to the Museum was his chief delight) and esteemed by his wide circle of friends, amongst whom the Stanleys and Huxleys were conspicuous. He was an ideal Christian character—guided by high principles and indifferent to mere superficial views and impressions, as his clergyman (Rev. Gerald Blunt) briefly wrote.

He was, besides, genial and considerate to all with whom he came in contact, so that no one could better have filled the important positions he successively occupied. Taken all in all, we shall not soon see so talented and so accurate a comparative anatomist, so impressive a speaker, so facile an artist, or a public man with a higher type of character. As was said by Professor Osborne of Professor Baird and Dr. Brown Goode, he "entered into the larger conception of the wide reaching responsibilities of his position under the Government, fully realising that he was not at the head of a university or of a metropolitan museum, but of the museum of a great nation."

W. C. M.

Right Rev. CHARLES GRAVES, Bishop of Limerick. 1812–1899.

Charles Graves was born in Dublin on November 6, 1812. He was the youngest son of Mr. John Crosbie Graves, of the Irish Bar, Chief Police Magistrate of Dublin, and Helena, daughter of the Rev. Charles Perceval. He received his early education at a private school near Bristol. He entered Trinity College, Dublin, in 1829, and obtained a scholarship—a distinction at that time given only for classical proficiency—in 1832; he graduated, in 1834, as the First Senior Moderator and Gold Medalist in Mathematics and Mathematical Physics of his year. He was elected to a Fellowship in 1836, and took deacon's orders in the same year. He was appointed the Professor of Mathematics in the University of Dublin, in succession to the celebrated James McCullagh, in 1843. He married, in 1840, Selina, daughter of Dr. John Cheyne, Physician to H.M. Forces in Ireland. Graves was made Dean of Clonfort in 1864, and was promoted to the Bishopric of Limerick, Ardfert, and Aghadoe in 1866, during the viceroyalty of Lord Kimberley, being one of the last bishops appointed before the disestablishment of the Irish Church. His manners were characterised by dignified courtesy, and, in his hours of relaxation, by a genial and cordial ease and freedom. His wide culture, keen intelligence, and conversational powers made him a most attractive and agreeable companion. His calm judgment in practical affairs, combined with his fine tact and temper, have been justly and highly commended. By his liberal feeling towards those who differed from him and his kindness of disposition he won the esteem and regard of all, and especially of the people of the diocese over which for thirty-three years he presided, without distinction of sect or party—sentiments which were exhibited in a marked manner on the occasion of his funeral.

In 1841 he published a translation of the two elegant memoirs of Chasles 'On the General Properties of Cones of the Second Degree and of Spherical Conics.' In the copious notes which he appended to this translation, he gave a number of new theorems of much interest, at which he arrived by Chasles's mode of treatment. Amongst these may be mentioned his extension of the construction of an ellipse, as traced by a pencil which strains a thread passing over two fixed points, by substituting for those points a given ellipse, with which the locus described is confocal. This he deduced from the more general theorem on Spherical Conics; the latter being arrived at from its reciprocal theorem,

viz., if two spherical conics have the same cyclic arcs, then any arc touching the inner curve will cut off from the outer a segment of constant area. It may be here observed that Bertrand, in his great treatise on the Integral Calculus, attributed the foregoing theorem of Graves to Chasles, who had subsequently arrived at it by an independent investigation. In a long appendix to the volume Graves gave a method of treating curves on a sphere corresponding to the Cartesian method on the plane, arcs of great circles taking the place of right lines. This theory he worked out in detail, supplying expressions analogous to the fundamental formulæ of plane analytic geometry, such as those for tangents, normals, osculating circles, evolutes, &c., and for the transformation of spherical co-ordinates. The whole was the fruit of Graves's independent research, though after the preparation of the Appendix he discovered that Professor Gudermann had partly anticipated his method, and that the properties of spherical curves had been previously studied by Mr. Davies, who, however, used only polar co-ordinates, whilst those principally employed by Graves were rectangular. This memoir was greatly admired by Sylvester and other mathematicians, but their high expectations of its fertility have not been fulfilled.

This was the only mathematical book which Graves published. His other investigations were either embodied in the lectures which he delivered as Professor of Mathematics in the University, or in papers read before the Royal Irish Academy. Having been elected a member of that body in 1837, he filled successively the offices of Secretary of the Council and Secretary of the Academy, and was elected its President in 1861. About the same period, Sir William R. Hamilton, McCullagh, and Humphry Lloyd were also members, and the meetings were often made the occasion of announcing the results of the spirit of scientific investigation which then so remarkably prevailed in the University of Dublin.

While Hamilton was explaining to the Academy in a series of communications his new Calculus of Quaternions, several contemporary mathematicians were led to conceive systems more or less analogous to his, and like it, involving new imaginaries. Graves proposed a system of Algebraic Triplets of this kind. But it must be said of it, as of the other similar systems, that it could not lay claim to anything like the power and flexibility of the Quaternions, and was not, indeed, so much a working method as an interesting mathematical curiosity. Other papers of his, published by the Academy, related to the theory of differential equations, to the solution of the equation of Laplace's functions, and to curves traced on surfaces, particularly on surfaces of the second degree. He gave a simple geometrical proof, published also in 'Crelle's Journal,' of Joachimsthal's theorem, viz., *that at all points of a line of curvature on an ellipsoid, the product* PD *is constant*,

where P *is the central perpendicular on the tangent plane, and* D *is the diameter drawn parallel to the element of the line of curvature.* He also gave some very valuable applications of the Calculus of Operations to the Calculus of Variations, and especially arrived at a simple proof, by the Operational Method, of Jacobi's celebrated theorem for distinguishing between maxima and minima values in the application of the Calculus of Variations to single integrals.

On the death of Hamilton in 1865, Graves delivered from the Presidential Chair of the Academy an eloquent *éloge* of that eminent man, containing an interesting account of both his scientific labours and of his literary attainments.

Graves had much literary and artistic taste and cultivation, and to these were, no doubt, largely due the symmetry and beauty both of method and of results which are marked characteristics of his mathematical work.

As a member of the Academy, he devoted much time and thought to antiquarian subjects in connection with Ireland. It is a striking evidence of his versatility and varied accomplishments, that the eminent antiquary, George Petrie, having died shortly after Graves had paid the above recorded tribute to Hamilton's memory, he pronounced a *éloge* on him also, and was able to give as clear and competent a survey of the archæological researches of the one as he had done of the scientific investigations of the other.

A subject which he studied with special zeal was that of the Ogham inscriptions, so numerous in Ireland. He applied to the characters employed in them the accepted methods for the decipherment of writings, known or presumed to be alphabetical, and in this way confirmed the interpretation of these symbols which is given in some of the old Irish books. He then proceeded to give readings and to prepare renderings of a number of the actual inscriptions on cromlechs and other stone monuments. The subject is still surrounded with difficulties, and many archæologists have been led to entertain the view that the inscriptions, at least in some cases, are intentionally cryptic.

Graves brought before Government, in a special publication, the importance of having the old Irish laws, commonly called the Brehon Laws, edited and translated by competent scholars. The suggestion was adopted, and, when the project was taken in hand, he was appointed a member of the Commission charged with carrying it into effect, and held this office till his death, which took place on July 17th, 1899.

Graves was elected a Fellow of the Royal Society in 1880, and the Honorary Degree of D.C.L. was conferred on him by the University of Oxford in 1881.

B. W.

JOHN JAMES WALKER. 1825–1900.

John James Walker was born at Kennington, Surrey, on the 2nd October, 1825, and received his early education partly at the London High School and partly at the Plymouth New Grammar School. His father, John Walker, was successively Head-master of those schools during this period. The family on the father's side was originally derived from Yorkshire, but had been settled in Ireland for several generations. Matthias Walker, the great-grandfather, John Walker, the grandfather, and John Walker, the father of the subject of this notice, were graduates of the University of Dublin. On his mother's side, Mr. J. J. Walker was mainly of English descent.

John Walker, the grandfather, was in orders of the Church of Ireland, and held a distinguished position as fellow of Trinity College, Dublin. He edited several classical text-books, formerly much in vogue among the students of the College, and also published works on elementary mathematics and logic.

As a natural consequence of the long connection of his family with the University of Dublin, Mr. J. J. Walker proceeded to Trinity College, and graduated at the Associated University of Dublin, B.A. in 1849, and M.A. in 1857. But he entered the College labouring under serious drawbacks, for it appears that owing to a notable evangelical movement which disturbed the official theology of the College and University, the representatives of Mr. Walker's family ceased to be conformists.

In the Book of Trinity College, published at the tercentenary (1591—1891), it is recorded of Kearny, the last Provost of the eighteenth century, "his only notable act was to refuse, with tears in his eyes, the resignation offered him, on the ground of religious difficulties, by the pious John Walker, and to expel him publicly on the next day."

Mr. J. J. Walker therefore was debarred from competition for scholarship or fellowship, and lay under other discouraging disabilities. The early death of his father hampered his resources, and made it desirable that he should, while still an undergraduate, take pupils when the opportunity offered. Nevertheless, he passed through the usual undergraduate course with great credit. After obtaining intermediate honours, he was Gold Medallist and Senior Moderator in Mathematics and Physics at the degree examination, and the year after (1850) obtained the second Bishop Law's prize, an honour highly esteemed in the College.

On the completion of his academical career, Mr. Walker engaged permanently in educational work. From 1853 to 1862 he was private tutor in the Guinness family. Soon after the close of this engagement he migrated to London, and in 1865 was appointed Afternoon Lecturer on Applied Mathematics and Natural Philosophy at University College School. In the same year he became a member of the London Mathematical Society, then recently formed. He was President of that Society 1888-90, and later on he became a member of the Physical Society. In 1883 he was elected Fellow of the Royal Society of London. His connection with University College School terminated in 1888, and his extended leisure was afterwards devoted to original research.

From 1868 to 1882 he was Vice-Principal of University Hall, and from 1871 to 1883 acted as examiner on Mathematics for the Hibbert Scholarships.

Mr. Walker was of a reserved temperament, marked by a somewhat precise courtesy of manner which seemed to belong to a bygone generation. His real kindliness was shown by genial estimates of character and liberal appreciation of the labours of others engaged in kindred studies. He died on the 15th February, 1900, at Hampstead, where he had resided for some years. In 1874 he married Emma (youngest daughter of the late Mr. William Turner, of Newcastle), who survives him.

Numerous communications to leading scientific journals are due to Mr. Walker's diligence. They range from brief papers relating to particular problems of theoretical mechanics to elaborate memoirs on the higher algebra and geometry. Several papers show practical skill in the application of Hamilton's Quaternions to special and elementary problems, and he held the opinion that this method had been too much neglected as an instrument of research. Mr. Walker's most valuable work, however, was on the lines of the higher algebra as set forth in Dr. Salmon's famous text-books. Thus in the Proceedings of the London Mathematical Society we find three connected papers on a method in the Analysis of Plane Curves and Curved Lines. In these are developed the methods employed in the 9th Chapter of the Treatise on the Higher Plane Curves (2nd edition). In other papers particular attention is given to cubic curves. This study led up to the memoir, "On the Diameters of Cubic Curves," printed in the Transactions of the Royal Society in 1889. In fact, Mr. Walker fully appreciated the modern operational methods, and his papers merit the attention of all who apply themselves hereafter to the advancement of the higher algebra and its application to geometry.

S. R.

ST. GEORGE MIVART. 1827–1900.

St. George Jackson Mivart, of Welsh descent, was born at Brook Street, Grosvenor Square, on November 30, 1827, and educated at Clapham, at the school of the late Rev. Dr. C. Pritchard, and at Chiswick, afterwards at Harrow and King's College, London. It was intended that he should go to Oxford, but as he had meanwhile (1844) become a Catholic, his education was completed at St. Mary's College, Oscott. He was, in 1851, called to the Bar at Lincoln's Inn; but, drifting instinctively into Natural History pursuits, he, eleven years later, obtained the appointment of Lecturer on Zoology at St. Mary's Hospital Medical School, which he held until 1884. While there, he published his first paper and his first book—the former (1864) entitled "Notes on the Crania of the Lemuroidea," the latter (1871) on 'The Genesis of Species'; while, immediately following this, he produced a manual for students, which is still in circulation, under the title of 'Lessons in Elementary Anatomy' (1873). The publication, thus rapidly, of a paper involving a considerable amount of detailed observation and description, of one volume aimed at nothing short of a bold attack on the Darwinian doctrines, then slowly gaining ground, and of another of the nature of a compilation from a voluminous literature, showed Mivart to be an investigator and writer of no mean order, provided his works were sound. It is now a matter of history that his 'Genesis of Species' brought him into conflict with Huxley in 1872, in the pages of the 'Contemporary Review,' with the result that while his book passed rapidly through a second edition, he and Huxley became estranged. Mivart's zoological work, as far as it has advanced knowledge, lay wholly with the Vertebrates, but he nevertheless essayed in the later 'seventies a series of articles in the 'Popular Science Review' on certain Invertebrates. Each of these bears as its title the name of a typical representative of a class ("Lobster," "Cuttle," "Echinus"), but is in reality an attempt at a very elementary survey of this, based on the fuller study of its most easily accessible genus. During the period of the production of these articles and again in later years, Mivart attended Huxley's lectures at the Royal School of Mines. In his article "Lobster" he admitted his indebtedness to Huxley's teaching, and in conversation with the writer he admitted it for his 'Lessons'—wherefore it would appear that these, his early works for the student, rank among the first products of the Huxleyean influence, at the time at which Huxley was arriving at the

full conception of his famous "Type System," which permeates all his later educational books, and of which the germs are in reality to be found in his 'Physiography,' originally delivered at a course of lectures in 1869 and again in 1870, at some of which Mivart was present.

Mivart will be best remembered in history as he who most steadfastly opposed the subsidiary doctrines of Darwinism, and the theory of "Natural Selection" in particular. He tells us in his writings how he at first embraced the latter, as formulated by Huxley; but he very soon forsook it—and, remaining an Evolutionist, for the rest of his life defended with reiterated emphasis the argument that evolution proceeds from some internal force directed towards definite ends, and that it is due to processes which are sudden and distinct, and not to gradual changes. To him, the one central zoological fact which clenched this argument was the vestigial state of the index finger of the Potto, which, while later studying the Lemurs as a series, he came to regard as the culminating phase of a modification common to them all but one. He was never tired of reverting to this, both in his later writing and in conversation. The Potto's manus figures on the title-page of his 'Genesis of Species'—his first book, and he came to the fuller study of the Lemurs through his first paper, wherefore the main tenour of his life's work is seen to have been the direct outcome of his earliest impressions.

Much of his later work, both as a practical anatomist and a philosopher, further reveals the impress of these; for, while we find him in later years returning to the study of the Lemurs, we note that he extended his observations from their skeleton, to the brain, and, less conspicuously, the muscles and viscera, of both them and the higher Apes, in a series of memoirs which, as accurate records of observed facts, will always remain valuable. And there is reason to associate his work upon the brain, the surface anatomy of which he carefully described in a large number of Mammals, with his famous argument, that psychical operations fall under two classes —"sense perceptions" alone performed by the brutes, and "intellectual perceptions" which, with them, being performed by man, involve him in a dual psychical nature. Right well did he defend this, more especialy in his 'Origin of Reason' (1889), and his conviction, based upon it, that a passage from the "mind" of the brute to the conceptual mind of man is inconceivable.

It is in connection with these beliefs that Mivart will best be remembered as a philosophic writer; and, apart from those works already alluded to as directly concerned with their elaboration and support, he published others dealing with them and cognate subjects. His 'Nature and Thought—an Introduction to Natural Philosophy' (1882), and his latest philosophic work 'The Groundwork of Science' (1894), may be here named—the latter a most elaborate study of

"Epistemology"—an attempt to define the basis of human knowledge, and to found a science of the sciences.

While in these writings Mivart has provided the thinking public with an immense amount of material for reflection and careful consideration, he has placed the world of working zoologists under a deep obligation for his numerous memoirs and papers, which are for the greater part painstaking records of structural detail, of immense service for reference. Some 73 in all—they are, with the exception of four, the work of his own hand; those in which he was assisted being memoirs on the anatomy of *Hyrax*, *Nycticebus*, and the Lemurs, written in conjunction with Dr. J. Murie, and a paper with the Rev. R. Clarke, "On the Sacral Plexus and Sacral Vertebræ of Lizards and other Vertebrata," which contains some facts of much interest in relation to the question of shifting during growth. Of the 73 works, 28 are devoted to the Mammalia, 6 each to Birds and Batrachia, 2 to Reptiles, and but 1 to Fishes. Beyond these, there are a number of magazine articles on other than controversial subjects, and reports of popular lectures, delivered at the Royal and London Institutions, the Zoological Gardens and elsewhere, but they call for no special comment. He also wrote three articles in the ninth edition of the 'Encyclopædia Britannica,' viz., "Ape," "Reptilia" (Anatomy), and "Skeleton"; but while voluminous, these are neither remarkable for any striking originality nor wholly free of error.

Mivart's papers on the higher Amniota are predominant among his scientific writings, and their contents are but little concerned with anything beyond the examination of external characters, the dried skeleton, and the surface of the brain—*i.e.*, he was not an anatomist in the broad sense, given to elaborate dissection of parts difficult of access; for, with the exception of certain dissections of the muscular system of animals he described, his "laboratory work" was done by deputy, as, for example, with his book on 'The Cat,' in which he was again aided by Murie. His best work is that upon the skeleton of Mammals and Birds, and chief among his papers are those dealing with the skeleton of the Primates and the Insectivora, which are laborious, and will always be of use for reference, and mark the introduction of terms which have been of great service. His papers on the Carnivora are also important, those dealing with the Æluroidea and Arctoidea being very welcome extensions of the late Sir W. Flower's, in which these names were originally introduced. "Man and the Apes" came under his consideration, and he has done good work in the detailed anatomy of their limb-bones; while not a few rarities have fallen to his lot, as for example, the scarcer Madagascan Lemurs and Insectivores and the Batrachian *Plethodon*.

The aforementioned papers are collectively a valuable series, and conspicuous among the more generally interesting results which they

embody are the orientation of the surfaces and processes of the monotreme shoulder-girdle, based on the study of its mythology; the discovery of the "Ursine lozenge" in the brain of the Sea Lion, and consequent support of the Arctoid affinities of the Pinnipedia; the conclusion that the Batrachia-Aglossa are a natural group; and, finally, his growing conviction that the Lemurs are a sub-order distinct from man and the apes, and that they have been wrongly included in the Primates, for which he argued more and more emphatically in some of his later works.

More sensational was his paper in the Proceedings of the Royal Society 'On the Possibly Dual Origin of the Mammalia,' in which, on the basis of the structure of the calcified teeth of *Ornithorhynchus*, he attempted to argue that the Mammalia may be diphyletic, and his remarkable memoir on the 'Fins of Elasmobranchs, and the Nature and Homologues of Vertebrate Limbs,' in which, contemporaneously with the American Thacher, he formulated the lateral fin-fold theory of the origin of these. This, on the whole, is his *chef-d'œuvre*, and except for error by failure to appreciate the fact that in the Batoid type, which he regarded as the most primitive, the forward extension of the pectoral fin is secondary and due to rotation, the theory is still in favour. In the manner in which the analogy between the behaviour of the corresponding parts of the median and lateral fins was utilised in defence of the theory, the memoir will always remain exemplary; and no slight public service was done at the time, by associated articles in the magazines and by popular lectures on the general subject of "Limbs," "Hands and Feet," in which all was treated in an up-to-date manner. This memoir presents Mivart at his very best, and if he had done nothing else he would through it have left his mark on the progress of science.

Much of his work lay with the Carnivora, as already remarked, and he in 1881 published a book of 530 pages upon 'The Cat,' with over 200 illustrations. Not only was this largely superflous beside the existing memoirs of Straus-Durckheim and others, but it was disappointing; and it may be said of it that while it contains a good deal that is general and useful on the first principles and elements of mammalian morphology, it often fails just where aid is mostly needed with the animal with which it deals. Similarly, his papers on the Dogs led up to an elaborately-illustrated book, in which all the known species of "Dogs, Jackals, Wolves, and Foxes," are said to be described. Of this book, produced in haste, none but an adverse judgment can unfortunately be given; since, for want of depth of research, it is of little use to the systematist, and, in places, misleading to the public.

Huxley's 'Crayfish (an Introduction to the Study of Zoology)' appeared in 1880. Mivart's 'Cat (an Introduction to the Study of

Back-boned Animals)' in 1881; and, similarly, while his book on the Canidæ followed a memoir by Huxley on the same subject, a close parallelism between other writings by the two men is recognisable.

Mivart was ever a controversialist in matters other than of philosophic doubt, and a keen upholder of priority. In proof there may be cited his share in defining the limitations of the term "Homology" in 1870, his justification of Owen's claims to have anticipated in 1848 the essence of the Weismannistic doctrines of the Immortality of the Protozoa and the Germ Plasma; and his defence of Buffon, when, in his Address as President of the Biological Section of the British Association, at its meeting of 1879, he sought to show that the claims of this bold generaliser (a man after his own heart) were overshadowed by those of Linnæus, on account of the two men having entered the world and achieved fame contemporaneously.

Continuing to contribute popular articles on Natural History subjects to the magazines throughout the 'eighties during which he published (1876) his well-known work on 'Contemporary Evolution,' Mivart produced both books and essays until writing became almost a mania, pursued it would seem in some cases for mere effect. In 1892 he produced a work entitled 'Birds: The Elements of Ornithology,' in which he adopted the classification of Seebohm, which does not find favour among working ornithologists, and stated contradictions which a little more field natural history would easily have dispelled; and in 1893 he published a book on 'Types of Animal Life'—really an elementary treatise on the Vertebrata, in which the object of the method or arrangement is somewhat unintelligible and the head-lines are misleading. In 1894 he essayed the task of dealing under one cover with the elementary principles of all branches of science, including history and mathematics, and in this book, termed 'Elements of Science,' which he dedicated to his father, he attempted an impossible task. Finally, in 1896, having during the preceding two to three years published a series of papers on the Osteology of the Parrots, which will be of great service to working zoologists, he produced a richly illustrated monograph on the 'Lories,' *en suite* with that of 1890 on the Canidæ, though much more thoroughly done and reliable.

With this memoir Mivart's career as a scientific worker ceased, but he continued writing; and as failing health overtook him he induced the reproach of the Catholic Church, by entering into controversy with Cardinal Vaughan, who, it is sufficient here to remark, anathematised where he was unable to refute, and brought about an excommunication.

Not content with this, Mivart, in the closing days of his life, revived a novel written years before, and, under the title 'In Castle and Manor,' completed it and secured its publication a week before his death.

He lived during middle life at 71, Seymour Street, W., and at Wilmshurst, near Fletching, in Sussex, and afterwards at Chilworth, in Surrey. Leaving there in 1894, he led a roaming life for a few years both at home and abroad, imagining himself a *malade*, until he finally settled in London, at 77, Inverness Terrace, Bayswater, where, after a series of heart attacks, which for the time being prostrated him, but which he threw off with magnificent vitality, he died suddenly on April 1, 1900, vigorous till the end.

Mivart was of imposing physique, dignified and stately in manner, and of a most charming temperament. As a host, he was ideal; courteous, chivalrous, and considerate to a degree. A brilliant conversationalist, a fluent French scholar, he was quick to perceive and ready of repartee, and he had the power of making the most of every information which came in his way and of the aid of others in his scientific work. He loved history, hated poetry, and as a writer was always worth reading when at his best, as, for example, in his two volumes of collected reprints entitled (1892) 'Essays and Criticisms.'

Apart from the Lectureship already alluded to, he was in 1874 appointed to the Professorship of Biology in the newly-established but very short-lived Catholic College at Kensington; and during the years 1890—1893 he was Professor of "The Philosophy of Natural History" at the University of Louvain. This post he filled at the urgent request of the University authorities, who desired modern philosophic and scientific teaching for certain of their clerical students. Mivart's teaching, however, was too "tough" for clerical digestion, and as he was asked to accept the Professorship so was he asked to resign it. He delivered at Louvain two or three courses of lectures, which he gave in French.

From Louvain he received in 1884 the M.D., and from Rome in 1876 the Ph.D. He was elected a Fellow of the Royal Society in 1869, and was a Fellow of the Linnean, Zoological, and other scientific societies, on whose Councils he frequently served. He was several times a Vice-President of the Zoological and Linnean, and was for six years Zoological Secretary to the latter. He was also a Corresponding Member of the Philadelphia Academy of Sciences.

G. B. H.

EDWARD JOSEPH LOWE. 1825–1900.

EDWARD JOSEPH LOWE was born at Highfield, near Nottingham, in 1825, and was elected into the Royal Society in 1867. He was in his sixteenth year when he began that series of meteorological observations and records which terminated only when, in 1882, he quitted Highfield, and took up his residence at Shirenewton Hall, near Chepstow. He was one of the founders of the Royal Meteorological Society, and assisted the late Professor Baden Powell in his observations on meteors for the British Association.

In 1860 he accompanied the Government Eclipse Expedition to Spain, taking charge of the meteorological department.

Mr. Lowe's meteorological work commenced at a very early age, and in this department he apparently continued a series of observations at Highfield House, Nottingham, that had already been begun; for a printed table of "Meteorological Observations made at and near Highfield House Observatory" appeared in 'Recreative Science,' giving the mean temperature for each month from 1810 to 1859. His own observations appear to have commenced in 1840, and were continued till 1882. From June 10, 1872, till April 3, 1882, he reported observations by telegraph to the Meteorological Office, and from 1874 till 1882 he contributed returns of observations made at 0h. 45m. P.M. each day to a collection of synchronous observations made at nearly fifty stations in the British Isles, or in British possessions, for transmission to the United States.

But the contribution of numerical data was not by any means the limit of his activity. He collected, from very various sources, information concerning meteorological phenomena, and discussed it sometimes synoptically—as in the attempt to give a presentation of the state of the weather over England during certain conspicuous thunderstorms, which is contained in his Treatise on Atmospheric Phenomena (1846); or during the eclipse of March 15, 1858*—sometimes chronologically, as in his pamphlet on the Chronology of the Seasons (1870), which gives an account of remarkable frosts, droughts, and other exceptional phenomena, which have been recorded as occurring in the British Isles since A.D. 220.

This latter work was to have been extended, and an introductory portion assigning an eleven years' cyclical period to droughts was in fact published in 1880 under the title "The Coming Drought, or Cycle of the Seasons"; but the question was not effectively worked out.

* 'Roy. Soc. Proc.' vol. 9, p. 213.

He dealt with familiar "Prognostications of Weather" in a pamphlet with that title published in 1849, and in conjunction with Mr. J. B. Scoffern contributed a small work on Practical Meteorology to Orr's "Circle of the Sciences" in 1856.

Many striking observations of halos and allied phenomena made by himself and others are collected and illustrated in the "Treatise on Atmospheric Phenomena." Mr. Lowe managed to record a hundred and ten solar and lunar halos within four years at Nottingham. Later on he added to the collection a very remarkable case, which is figured in 'Nature.'*

He gave his attention, amongst other things, to the improvement of the means for testing the amount of ozone in the atmosphere, and he also contributed papers to the Astronomical Journals on Meteors, Sun-spots, and on the Zodiacal Light.

In addition to his researches in physical science, Lowe was an ardent naturalist, publishing works on conchology, on British ferns, grasses, and ornamental plants. He was an enthusiastic gardener, and his experiments on hybridisation were as remarkable as they were numerous. The hybridisation of flowering plants can be effected directly and without doubt. It is different in the case of ferns. Admixture of spores taken from different plants and close approximation of different individuals can alone be practised, and the results are correspondingly uncertain. Prothalli are formed bearing antheridia and archegonia, from which latter, after fertilisation by the spermatozoid, the new plant is formed. In Lowe's early experiments (1855) the seedlings were nearly all normal, whilst now (1890) "it is difficult for me to raise a normal form, one or two marked varieties used to be the reward, now they can be counted by hundreds." Ultimately Mr. Lowe obtained results of an astonishing nature. At the Fern Conference held in the Chiswick Gardens of the Royal Horticultural Society on July 23, 1890, Mr. Lowe showed not one but several plants, resulting from what he considered "multiple parentage"—that is, on the same plant, nay even on the same frond, were clear evidences of the influence of different varieties, the spores of which had purposely been mixed together. "The third experiment," writes Mr. Lowe in the 'Journal of the Royal Horticultural Society,'† "was the mixing together the spores of half a dozen varieties of the lady fern, and as a further trial, half a dozen varieties of the hart's tongue. This brought out a new fact—there were seedlings that showed the characters of three and even four varieties on a single frond, so that male organs from several varieties had assisted in this impregnation. . . . . A further experiment with the hart's tongue is also of peculiar interest. An undulate form, a

* Vol. 15, p. 508.
† Vol. 12 (1890), p. 509.

spiral form, a rugose form, and a tasselled form were sown together, and amongst the seedlings there are plants that exhibit all these characteristics."

Such statements naturally excited some scepticism on the part of those who did not see the evidences; but there could be no doubt of the facts, which were shown in abundance on the occasion mentioned, and subsequently we believe at the Bristol Meeting of the British Association and elsewhere. It may be that the researches into the number and division of the chromosomes may ultimately supply the explanation of these extraordinary phenomena.

Lowe pursued his hybridisation experiments with other plants than ferns. Some of the latest specimens with which he favoured the writer were the result of crossing dahlias with the pollen of sunflowers. Whilst there was evidence of a change having taken place, as if the balance of nutrition and growth had been disturbed, there was no clear evidence of any intermixture of parental elements.

The full record of Mr. Lowe's experiments is given, with many illustrations, in his work entitled "Fern Growing," published in 1895, a work which must be carefully consulted by all succeeding workers in the same field.

Mr. Lowe's observations and experiments were not confined to plants, but were carried out with cattle, pigs, sheep, and fowls.

Mr. Lowe was an honest enthusiast, firmly convinced of the correctness of his own judgment; but in spite of the very remarkable evidence he brought forward, he did not in all cases succeed in convincing his fellows, who entertained some doubt as to the care that had been bestowed to avoid error in the performance of his experiments, and consequently as to their value and the interpretation to be put upon them. It is for others to repeat his experiments under more precise conditions.

In private life Mr. Lowe was a warm friend, ever ready to be of service to his fellows, and fulfilling the duties of a country gentleman as a Deputy-Lieutenant and magistrate. He died on the 10th of March, 1900, at Shirenewton.

M. T. M.
W. N. S.

GEORGE JAMES SYMONS. 1838–1900.

George James Symons was born at Queen's Row, Pimlico, on August 6, 1838, and was educated at St. Peter's Collegiate School, Eaton Square, at Thornton in Leicestershire, and at the School of Mines.

In 1856, at the age of 18, he was elected a member of the British Meteorological Society, now the Royal Meteorological Society. During these forty-four years he rendered invaluable services to the Society, as contributor to its 'Proceedings,' as member of council, vice-president, honorary secretary, and president; and in 1900 he was for the second time elected president in view of the jubilee of the Society, which was held in April. Indeed, it is very largely due to his able, well directed, and untiring exertions during these forty-four years that the Royal Meteorological Society holds its present position.

On the invitation of Admiral Fitzroy, he became a member of the staff of the Meteorological Department of the Board of Trade, in 1860; but this he resigned in 1863, in order to give his whole time to the collection of statistics of the rainfall of the British Islands. His first contribution to science was a paper on the thunderstorms of June, 1857, and it is interesting to note that it was during the investigation of this inquiry he received the bias towards rainfall inquiries, which rapidly became his absorbing life-work.

This life-work may justly be considered as having begun in earnest in 1860, by the publication of Rain Returns of that year, with the view of showing the then known distribution of rain over the British Islands. The large gaps this revealed in our knowledge of this important element of our British climate acted on Mr. Symons' mind simply as the strongest incitement to the establishing of numerous rain-gauges in all parts of these islands. In this work he at once evinced quite remarkable ability in establishing these stations, and in most effectively supervising them, and the statistics of rainfall supplied by them. By his well-directed energy, the results published in 1866 were justly regarded as fairly representative of the distribution of the rainfall of that year over the British Islands. In the last published Annual Rainfall, 1899, the number of Rainfall Stations is 3528, distributed thus—2894 in England and Wales, 446 in Scotland, and 188 in Ireland. During this long term of years, his relations with observers and societies, by letter or by personal visits, were most cordial, intimate, and continuous, the object aimed at, on all hands, being to make the record of the rainfall of each year as complete as

possible. The result attained is that the Rainfall System set on foot by Mr. Symons, and carried out by him for forty years, is the most complete anywhere existing, looking to the extent of country covered by the rain-gauges, and to the trustworthiness of the records thereby collected of this prime element of climate.

The chief books which he wrote or edited are the forty volumes of 'British Rainfall,' and the thirty volumes of 'Symons' Monthly Meteorological Magazine.' Soon after the eruption of Krakatoa, it was suggested that the Royal Society should appoint a Committee to undertake an exhaustive report of the eruption. Mr. Symons was appointed chairman of the Committee and edited the Report.

He was engaged for many years in compiling a catalogue of meteorological books and papers, which embraced a total of from 60,000 to 70,000 titles, and of these, in 1882, he contributed about 20,000 titles to a bibliography prepared by the Weather Bureau of the United States. His own private library numbered nearly 10,000 books and pamphlets, many of these being rare and in several cases unique copies of early meteorological works.

On February 14, he was struck down by paralysis. For a brief time he made some progress towards recovery; but unfavourable symptoms supervening, he died on March 10, 1900.

A. B.

HENRY HICKS. 1837–1899.

Dr. Henry Hicks was born in 1837, at St. David's, Pembrokeshire, where his father, Mr. Thomas Hicks, was a surgeon. After attending the Cathedral Chapter School of that place, he studied medicine at Guy's Hospital, becoming a member of the Royal College of Surgeons in 1862. Returning to St. David's, he practised there, but almost immediately, through the influence of the late J. W. Salter, was attracted to geology. His singularly acute eye made him most successful in discovering fossils, and the older palæontologist's enthusiasm over Hicks's finds was the best of stimulants. But at that date geology was not favourably regarded in clerical and county circles and to be suspected of it might have been injurious to the young practitioner. So, as Hicks used to relate in later years, he had to carry on geological investigation behind the screen of professional duties, and his servant must have often wondered at his master's fondness for leaving his carriage to walk home across the moor or along the cliffs. But his important discoveries soon made his name known far beyond St. David's, and in June, 1865, he read his first paper to the Geological Society, a note on the genus Anopolenus, appended to a shorter communication by Mr. Salter. This revealed his secret, but as he did credit to St. David's, his scientific aberration was more than condoned. His practice increased and was never neglected, though every spare moment was devoted to geology, and before long he was able to announce a great discovery, that of fossils in the red flaggy Lower Cambrian rocks of St. David's, hitherto believed to be totally barren. The paper by himself and Mr. Salter was read to the Geological Society in June, 1867. At that time a Lingulella only had been found in the lower beds, and very few fossils in the higher divisions, but stimulated by this success and a grant from the British Association, Hicks worked on so ardently, that by next year he had discovered thirty species, mostly trilobites, in the Cambrian of St. David's. He then proceeded to a thorough investigation of the overlying beds with excellent results. But in 1871 he decided to quit St. David's for the neighbourhood of London, and settled at Hendon as a general practitioner. About six years later he found an opportunity of restricting himself to mental diseases, and was head of a retreat for ladies thus affected. This proved very successful, and was afterwards transferred to Hendon Grove, which stands in spacious grounds sloping down towards the Brent. In 1878 he took the degree of M.D. at St. Andrews, and as his professional duties now were less

engrossing, he extended his range of geological work from the earlier palæozoics to the Pre-Cambrian rocks, and to the investigation of glacial deposits. But he was also active in local affairs, especially in questions sanitary and educational, as well as in church work, and in the organization of the Conservative party. In fact he was never idle. His sturdy frame, clear and ruddy complexion, dark hair only grizzling, unflagging energy, and seemingly abundant vitality gave promise of a long life. Of late years, however, he had suffered occasionally from rather severe attacks of rheumatic gout. One recurred in the autumn; it affected the heart, and he passed away on November 18, 1899, leaving a widow and three married daughters.

He was equally active in scientific organisations, taking part in the excursions of the Geologists' Association, of which he was President from 1883 to 1885, in the meetings of the British Association, and in the Geological Society of which he was Secretary from 1890 to 1893 and President from 1896 to 1898, being a member of the Council and Vice-President at the time of his death. By that society he was awarded the Bigsby Medal in 1883, and he was elected a Fellow of the Royal Society in 1885.

Hicks wrote, in addition to some medical notes, about sixty-three geological papers. The most important appeared in the 'Quarterly Journal of the Geological Society,' but he also contributed frequently to the 'Geological Magazine,' the 'Proceedings of the Geologists' Association,' the 'Report of the British Association,' 'Nature,' and other periodicals. These papers may be grouped under the following heads:—(1) The earlier palæozoic strata of Pembrokeshire. The first, as already stated, to discover fossils in the Lower Cambrian of St. David's, he afterwards proved that the beds beneath the Menevian (which was distinguished from the Lingula Flags by the joint work of himself and Salter), could be sub-divided into an upper or Solva group, characterised, like the Menevian by the presence of the trilobite Paradoxides and a lower or Caerfai group, which no doubt corresponds with the Olenellus zone, although that trilobite has not yet been identified with certainty at St. David's. But besides this, Hicks worked out the whole Pembrokeshire section upwards from the Menevian to the Llandeilo, indicating the position of important volcanic discharges and proposing to group the upper part of the Arenig with some of the Llandeilo as the Llanvirn beds. In one paper, published in the 'Journal of the Geological Society,' he reviewed the distribution and distinctive characters of the Cambrian and Lower Silurian strata of Europe, pointing out their bearing on the physical geography of those ages.

(2) The second group of papers, begun in 1877, dealt with the beds underlying a conglomerate which apparently serves as a base to the St. David's Cambrian. Of these he made two divisions, the upper

a group of porcellanites, volcanic breccias, and felstones for which he proposed the name Pebidian; the lower, consisting of highly crystalline rocks, which, however, he supposed had formerly been sediments, and called Dimetian. Next year he showed that similar rocks occurred in other parts of Pembrokeshire; in the following one, he separated under the name Arvonian, a group of hälleflintas, breccias, and quartz-felsites, which at first, so far as recognised, had been taken for the lower part of the Pebidian; recurring to that subject in later papers.

(3) Closely allied to this group of papers is a third one, begun in 1878 dealing with the Pre-Cambrian rocks of Carnarvonshire and Anglesey. In this district also Hicks maintained that an important series existed which was capable of sub-division into Dimetian, Arvonian and Pebidian. Here we may mention his interesting discovery, announced in 1868, of plant remains at the base of the Denbighshire Grits near Corwen. Over the Pre-Cambrians of Pembrokeshire and North Wales many battles have been fought and peace has not yet been proclaimed. Not a few geologists think Hicks to have been right in asserting the existence of a Pre-Cambrian series, containing both comparatively unaltered, and highly crystalline rocks, but that he was premature in attempting a definite classification. His Arvonian embraced rocks of very different characters, the most recognisable types of which seem better left with the Pebidian, while the original Dimetian (though a crystalline series undoubtedly exists), rested on an insecure foundation.

(4) In 1883 he boldly attacked the problem of the Scotch Highlands in a paper on "The Metamorphic and Overlying Rocks in the Neighbourhood of Loch Maree." In this he asserted that though the Glen Laggan section exhibited, as Murchison had maintained, an upward succession from the Torridon Sandstone to the so-called Newer Gneiss, the latter was not a highly altered rock, but that far behind it (in Glen Docherty) members of the Lower Gneiss series again rose up, and then passed southwards into the *massif* of the Central Highlands. The question was far too intricate to be settled in a comparatively short time, and his attack on the Murchisonian position was generally held to have failed; at the same time he had shown, and this was made yet clearer in two subsequently published papers on the Central Highlands, that the crystalline schists and gneisses, formerly mapped as Newer Gneiss, and regarded as metamorphosed Silurian, cannot be separated from the crystalline rocks beneath the Torridon Sandstone in the north-west. This is now generally admitted; the key to the enigma being the discovery of Professor Lapworth.

(5) This group deals with the other extreme of geological history. Boulder clays and some gravels occur near Hendon, and fragments of Mammalian bones have been exhumed in the valley below his

house. These Hicks described, and wrote also on the discovery of two skeletons of the Mammoth at the base of the gravel in Endsleigh Street, and on the excavations of the Ffynnon Beuno and Cae Gwyn Caves in North Wales, the contents of which he maintained to be pre-glacial.

(6) The latest, and smallest group of his papers, relates to North Devon. On a visit to Ilfracombe in 1890, he succeeded in finding one or two fossils in the Morte Slates, which he identified as Silurian, maintaining this group to be, not in its place as a member of a sequence, but an older mass, thrust through the broken Devonian series. Here again, as the Silurian age depended upon the identification of a Lingula, it was generally felt that the wiser course would have been to wait for more evidence. So Hicks continued to visit the district annually, and in 1896 and the following year laid the new evidence before the Geological Society. Even then the damaged condition of the fossils made precise identification difficult, and the Silurian age of the Morte Slates was held by some to be still unproved; but that they contain beds of different ages, and that thrust faulting on a considerable scale has occurred along this zone of North Devon is now generally admitted. We believe that he was still working on the question at the time of his death.

As a geologist, Hicks was singularly acute. His eye was so keen, his diagnosis, as it might be called, so shrewd, that he seemed almost to scent out fossils, and he carried on to non-sedimentary rocks the same power of noticing similarities and differences. The more difficult a problem, the greater was its charm for him. In drawing conclusions he was very quick—too quick perhaps, at any rate in publishing them; for while his main idea usually proved to be right, important details had afterwards to be corrected. But his work, like himself, was always stimulative. As may be inferred from this sketch of it, he was often involved in controversy, but he fought as if he rather enjoyed an intellectual battle, the stress of which never ruffled the course of friendship for more than a moment. A man in some respects unique, his unexpected death was a loss to geology, and a heavy blow to many sincerely attached friends.

T. G. B.

RICHARD THORNE THORNE. 1841–1899.

Richard Thorne Thorne began work in the public health service of the State in 1867, when he was selected by Mr. (Sir John) Simon to undertake certain sanitary inquiries for the Medical Department of the Privy Council. At that date Thorne was 26 years of age. He had graduated with distinction at the University of London, and was physician to the London Fever and to other hospitals. By 1871, when the Privy Council Medical Department was, with others, merged into the newly created Local Government Board, Thorne had become a permanent member of its staff, and thenceforward he served that Board successively as medical inspector, assistant medical officer, and chief medical officer. He had held the last of these offices nearly eight years, when his career of usefulness was terminated by his sudden death on 18th December (1899).

Under the Local Government Board, in the early days of its administration, there was curtailment of the original sanitary investigation—field work, as it might be called—which had characterised the régime of the Privy Council Medical Department. Certain opportunities, however, for work of this sort fell to Thorne, and he made full use of them. No research is better known, for instance, than his inquiry into an outbreak of enteric fever at Caterham, which he succeeded in referring to accidental specific pollution of the deep well-water which supplied that district; and it was at this stage of his career that, as occasion served, he pursued his studies of diphtheria. Meanwhile his administrative faculties were maturing which, in later days, found expression so greatly to the profit of his Department. In 1883, during the period in which the late Sir George Buchanan was his chief, Thorne was, on the retirement of Netten Radcliffe, appointed assistant medical officer of the Board. In this capacity, alike in the performance of exceptional duties and of day-to-day official tasks, he showed very special ability. He was keen to acquire knowledge which was being gained by workers in sanitary science at home and abroad, and particularly by his own Department under Buchanan's direction; and he was quick to see the applicability of such knowledge to practical sanitary administration. He had a habit of adopting in regard of a given subject so much as, in the light of current knowledge, bore directly on public health and was at the same time feasible in application from the administrative standpoint. The Local Government Board "Model" series of sanitary by-laws, and its memoranda on isolation hospital

construction, with both of which Thorne had much to do, are instances in point. Once such standards had been fixed, nothing would induce Thorne to assent to any proposals which fell short of them. One of the principal services which he rendered to his Department was collating and recording, in a way to evolve principles of action, sanitary intelligence from foreign sources. Thus it came about that he was in 1885 nominated by the Foreign Office as British Delegate to the International Conference on Cholera Prevention, at Rome; and he afterwards attended, in the same capacity, four similar conferences, the last being that which, in 1897, drew up the important Venice Convention. The duties of Great Britain's representative at these conferences were by no means easy. This country had adopted a system of defence against imported infectious disease at variance with all Continental practice of "quarantine," and of our policy in this respect Thorne was the verbal exponent. He had to convince delegates of other nations that our system of medical inspection in substitution for "quarantine" had not been resorted to merely to escape from tyrannous interference with traffic at our ports, but had been adopted in view of experience that, in point of public safety, "quarantine" was a mistaken and mischievous policy. Thorne had a talent for diplomacy of the sort which was here required, and from four successive conferences at Rome, Dresden, Paris, and Venice, he returned having achieved notable success. Nor was the advantage thus accruing confined to Great Britain, for his influence did much to bring foreign countries to revise their methods and to adopt sounder systems of precaution against imported cholera and plague.

From his appointment as medical officer, in 1892, to the date of his death, Thorne exercised a great and increasing influence in the counsels of the Board and the Government. He possessed the faculty, essential to the holder of his office, of forming rapid decisions, often at very short notice, upon the multitude of complex problems which came daily before him. He was elected a Fellow of this Society in 1890, was made C.B. in 1892, and was advanced to K.C.B. in 1897. He had conferred on him several Honorary Degrees. He was a member of the Royal Commission on Tuberculosis of 1896, and of that on Sewage Disposal which was appointed in 1898.

Though he would make up his mind as to the merits of a subject independently of outside influence, yet Thorne was keen that the medical profession and the public should know the facts and see them as he did. To this extent he attached much weight to the support of public opinion, and few men have done so much to educate the public mind in sanitary questions. He contributed frequently to medical and other periodicals, and now and again took part with effect, in discussions and conferences on pressing sanitary questions of the day. He was an admirable lecturer, and several of his addresses and

lectures, such as that on the "Progress of Preventive Medicine in the Victorian Era" (President's address to the Epidemiological Society, 1887); "Diphtheria, its Natural History and Prevention" (Milroy Lectures, 1891), are known to a wide public. The Milroy Lectures were indeed a conspicuous example of his ability to set out a highly complex subject in effective fashion. In many ways Thorne showed that he had at heart the best interests of the profession to which he belonged, and after his appointment in 1895 by the Crown to the General Medical Council, he took a leading part in the deliberations of that body. Here, as all through his career, men recognised him as of independent stamp, clear sighted, conscientiously striving to determine the right course, and above all tenacious of his purpose. In short, his were qualities needed in the holder of a high office in our Civil Service, and he made use of them in a way which called alike for the admiration and for the gratitude of the country.

W. H. P.

JOHN ANDERSON. 1833–1900.

JOHN ANDERSON was born on October 4, 1833, in Edinburgh, where his father, Thomas Anderson, was secretary to the National Bank of Scotland. From an early age he evinced a strong inclination towards natural history, collecting insects, shells, fossils, &c., as so many boys do, and his interest in zoology ever increasing as he grew, he determined to take up the study of medicine, which, in those days in Scotland, was the readiest means of qualifying in the department of science in which he was afterwards to fill so distinguished a place, and to the progress of which he contributed so efficiently.

After graduating M.D. of the University of Edinburgh in 1861, receiving a gold medal for a thesis on a zoological subject, and lecturing on natural science at the Free Church College of that town, he proceeded to India in 1864 to take up the post of curator of the natural history and archæological collections of the Asiatic Society of Bengal, which were to form the nucleus of a new Government museum at Calcutta, the previous curator, Edward Blyth, retiring through broken health after twenty-four years' service. The building had yet to be erected, and in this important matter the new curator's artistic taste and practical mind were of great assistance to the recently-appointed trustees of the museum, which was not completed until 1870. All this time, Dr. Anderson, whose title was changed soon after his appointment to that of superintendent of the museum, was busy extending the collections and improving their scientific arrangement, lecturing also at the Medical College of Calcutta, where he held the appointment of Professor of Comparative Anatomy from 1867 to 1887, and assisting, as honorary secretary, in the management of the newly-opened Zoological Gardens, the establishment of which had been warmly advocated by him. In connection with the latter function he was instrumental in sending to the parent institution in London many rare Indian animals, often at great personal trouble; the genuine interest he took in living animals was maintained to the last, and on many occasions since his return home have his donations enriched the menagerie in the Regent's Park.

At the time of Dr. Anderson's arrival in Calcutta, quite an extraordinary activity was being displayed in the field of Indian zoology. Blyth's Catalogue of Mammals (1863), Jerdon's three volumes on the Birds (1862–64), and Günther's beautiful work on the Reptiles (1864) had given a fresh impetus to the study of Vertebrates, and soon after

a phalanx of able and enthusiastic zoologists, among whom Beddome, Blanford, Day, Godwin Austen, Hume, Stoliczka, Theobald, and Anderson himself, were busy gathering material from all parts and publishing the results in the 'Journal' and the 'Proceedings' of the Asiatic Society of Bengal, the 'Proceedings of the Zoological Society of London,' the 'Annals and Magazine of Natural History,' as well as in special monographs. Anderson's share in the movement resulted in a Catalogue of the Mammalia in the Indian Museum (vol. 1, 1881), since completed by Mr. W. L. Sclater, his 'Anatomical and Zoological Researches' (1879), and numerous papers on Indian and Persian Reptiles and Batrachians. He paid special attention to the Chelonians of India and neighbouring countries, the study of which, through the somewhat eccentric systematic attempts of Dr. Gray at the time, had lapsed into a state of extreme confusion, which Dr. Anderson did much to clear up. One of his most important contributions to Mammalogy is a monograph of the extraordinary fluviatile Cetaceans *Platanista* and *Orcella*, which is incorporated in his 'Researches.'

Outside the domain of Zoology, he wrote a 'Handbook to the Archæological Collections of the Indian Museum, Calcutta' (two volumes, published in 1883 and 1884).

Notwithstanding his numerous duties as superintendent of the museum and his manifold voluntary occupations, Dr. Anderson found time to take part in two expeditions to Upper Burma and South Western China (Yunnan), which he accompanied in the capacity of naturalist and medical officer (1868–69 and 1874–75). The scientific results of these expeditions were made known by him in a paper on the sources of the Irawadi, contributed to the 'Geographical Journal' in 1870, in a report issued by the Government of India in 1871, in a book entitled 'Mandalay to Momien' (1876), and in a great illustrated work, which appeared in 1879 as 'Anatomical and Zoological Researches, comprising an Account of the Zoological Results of the Two Expeditions to Western Yunnan.' In 1880 he paid a visit to Egypt and Palestine, where he made some zoological collections; and in 1881–82 he undertook an expedition, on behalf of the Indian Museum, to Tenasserim and the Mergui Archipelago, with the principal object of investigating the marine fauna, an expedition which resulted in the publication, after his return to England, of a series of papers by himself and various specialists, in the 'Journal of the Linnean Society,' and afterwards reprinted, in 1889, as a work in two volumes, entitled 'Contributions to the Fauna of Mergui and its Archipelago.' This was supplemented by a book on the history of Tenasserim, which appeared in 1890 in Trübner's Oriental Series under the title of 'English Intercourse with Siam in the XVIIth Century.'

Dr. Anderson gave valuable assistance in the organisation of the International Exhibition held in Calcutta in 1883–84 under the presi-

dency of the Duke of Connaught. Dr. Anderson was on the Executive Committee, and was chairman of the Fine Art Section. His enjoyment of this work led him to devote the furlough immediately following the close of the exhibition to a visit to Japan, accompanied by his wife. The summer of 1884 was spent in traversing that interesting country, and through introductions from the Indian Government, the Japanese officials gave every facility for a thorough inspection of their art treasures.

Having retired from the superintendentship of the Calcutta Museum in 1887, and the elaboration of the materials amassed during his Indian career being completed, Dr. Anderson turned his attention to the fauna of the Mediterranean coast of Africa. Visiting Algeria and Tunisia in the winter of 1890–91, he collected a small but not unimportant series of mammals and reptiles, on which he reported in a paper read before the Zoological Society in 1892. But abandoning this comparatively well-explored district, he decided to concentrate his energies on the investigation of the vertebrate fauna of Egypt and neighbouring countries, a work which absorbed the whole of his activity down to his last moments, and by which the British Museum has been greatly enriched; the materials gathered with this object being generously presented by him to the national collection as soon as worked out. Full of enthusiasm in his new work, he made repeated visits to Egypt, proceeding even so far as Suakim, and succeeded in enlisting the co-operation of officials and travellers in Egypt, the Soudan, and Arabia, with the result of forming a large and important collection of reptiles from these countries, accounts of which have appeared in various papers, in a small volume, 'Herpetology of Arabia' (1896), and finally in an admirable and lavishly-illustrated monograph of the Reptiles and Batrachians, forming the first volume of his 'Zoology of Egypt,' published in 1898. This great work, through the care with which it has been prepared and the beauty and accuracy of its coloured illustrations, mostly executed from living specimens by an accomplished artist (Mr. P. J. Smit), may be said to constitute one of the noblest contributions to faunistic zoology which has ever appeared. It would very soon have been followed by a similar volume on the Mammals but for the author's sudden death. Since his return from India, Dr. Anderson's health had never been perfectly satisfactory, and a catarrhal affection, combined with weakness of the heart, had, of late years, frequently prostrated him and confined him to his house for weeks at a time. A chill contracted whilst staying at Buxton in the summer of 1900 terminated there fatally, after two days' illness, on August 15th. He was interred in Edinburgh.

Allusion has been made above to the unfinished work on the Mammals of Egypt, but it is a satisfaction to know that its publication is only deferred, and will be carried out under the direct supervision of

the devoted companion of Dr. Anderson's life, whose sympathy with her husband's scientific pursuits made it a delight to her to accompany him in his travels and to watch the progress of his indefatigable industry in working out the materials gathered on these occasions.

This sketch of Dr. Anderson's life gives some idea of the variety of his occupations and of his extensive knowledge in various departments of science and art. But only those who have had the privilege of his personal acquaintance can realise the many-sided character of his tastes and the charm of his manner, which endeared him to all with whom he came in contact, and the remarkable tact which rendered his dealings with high officials so eminently successful, and led to results by which his favourite science was directly benefited. His latest achievement in this direction was the organisation of a survey of the Fishes of the Nile, now in progress, undertaken as a result of his application to the Egyptian Government, supported by the Presidents of the Royal and Linnean Societies, the Secretary of the Zoological Society, and the Director of the Natural History Museum.

Dr. Anderson was elected a Fellow of the Royal Society in 1879. The University of Edinburgh conferred on him the honorary degree of LL.D. in 1885. For many years he sat on the councils of the Linnean and Zoological Societies, which he also served as a vice-president.

G. A. B.

WILLIAM POLE. 1814–1900.

William Pole was born in Birmingham on the 22nd April, 1814. After receiving a good ordinary education in a private school, he was articled to an Engineer connected with large mechanical works in the neighbourhood, and so obtained a thorough foundation of practical knowledge. After the expiry of his articles he removed to London, served for some years as assistant to eminent men in the profession, and ultimately established himself in Westminster as a Consulting Engineer on his own account.

He had a natural inclination for science, and he soon found out that at that time scientific considerations were but little attended to by professional engineers. The best works constructed were due to the acuteness of men of superior natural ability, while more ordinary practitioners were content with either imitating them, or, in new wants, relying on published rules and tables, with very little regard to their authority or their applicability. And, indeed, the few persons who professed to meddle with science were often sneered at as "theorists," under the impression that "theory" and "practice" were irreconcilable. And this notion was partly confirmed by some mistaken endeavours on the part of educational bodies to establish theoretical "schools" (or "classes") of Engineering, where the "practical" qualifications were as much neglected as the "theoretical" ones had been among the working profession. It was imagined that high mathematics, combined with occasional amusement in a toy workshop, would suffice to form a professional engineer, an idea that resulted in ludicrous failures.

Mr. Pole, during his early years in London, strove to supply, by study, the scientific knowledge, chiefly mathematical and physical, which he believed necessary for his profession, and he was fortunate enough to gain the friendship of Professor Henry Moseley, F.R.S., who was just then preparing his admirable treatise on "The Mechanical Principles of Engineering and Architecture." This work inaugurated the true scientific education of the profession (since become so much extended), as it aimed at giving students sound and sufficient theoretical knowledge before they undertook their necessary practical training.

Professor Moseley was then acting as the representative of a Committee of the British Association for carrying out "Experiments on Steam Engines" with apparatus of great novelty and merit, designed

by Poncelet and Morin, and he paid Mr. Pole the compliment of transferring the work to him. Mr. Pole completed the experiments, and his Report, dated April, 1844, will be found in the Proceedings of the Association for that year.

The engine which had been experimented on was a "Cornish Pumping Engine"; and as this form of engine had excited much interest among Mechanical Engineers, Mr. Pole took the opportunity of studying it thoroughly, and publishing a somewhat elaborate treatise upon it, in which the British Association experiments were further discussed, and their practical application was more extensively explained.

In 1844 the East India Company established a class in the Elphinstone College, Bombay, for training some of the best educated native young men as Assistants on Public Works, and Mr. Pole was appointed "Professor of Engineering" for the purpose. He filled the office till 1847, when he was obliged, by reason of his health, to return home and resume his practice in London. At a later time (1859) he accepted a similar appointment in University College, London, which he held for some years.

He undertook much scientific Engineering work for the Government. In 1857 he reported on some elaborate hydraulic questions connected with Metropolitan Main Drainage. From 1861 to 1864 he served as a Member of the Iron Armour Committee, who, by careful study and long-continued experiments, laid the foundation of the knowledge on this important subject, since so largely applied.

He was chosen, on account of his technical and scientific acquirements, as Secretary to three Royal Commissions of much public importance—namely, that of the Duke of Devonshire in 1865 on Railways; that of the Duke of Richmond in 1867-9 on Water Supply; and that of Lord Bramwell in 1882-4 on the Purity of the Thames. He also rendered special aid to the Government in their introduction into London in 1871 of the System of Constant Water Service.

He was engaged to deliver periodical lectures on the principles of Civil Engineering to the students at the Royal Engineer Establishment at Chatham, and, following up the Iron Armour investigations, he gave a course (afterwards published) to the Royal Naval School on the structural use of Iron generally.

In 1871 he held, for the India Office, a Public Engineering Examination of Candidates for employment on the Public Works of India.

In 1870 he was nominated by the Board of Trade as one of the "Metropolitan Gas Referees," a scientific body established by Parliament to control the gas supply of London. This office he held for more than a quarter of a century.

Mr. Pole's private practice extended to a great variety of work, in

much of which his scientific acquirements were turned to good account. He was specially engaged in the calculations for several large bridges, in regard to some of which serious disputes had arisen. His theoretical work on the great Britannia Bridge was afterwards published by the desire of Robert Stephenson. He received a Telford Medal from the Institution of Civil Engineers, and a Silver Medal from the Society of Arts for applications of science to engineering problems. In one case he facilitated a large and novel sewerage design by pointing out modern French discoveries in hydraulic theory. He had much practice in mechanical work; he superintended the provision of large railway appliances, and was for many years Consulting Engineer for the Government Railways of Japan, for which he was decorated by the Mikado with a high grade in the Imperial Order of the Rising Sun.

He was one of the oldest living Members of the Institution of Civil Engineers. He served twelve years on the Council, and held from 1885 to 1896 the office of honorary secretary. In the latter year he was elected by a special complimentary vote an honorary member.

In addition to his ordinary business he did much literary work; he wrote the biographies of some eminent engineers, and a great number of articles bearing on science, some in first-class periodicals.

He had studied astronomy; while in India he calculated and published the Orbit of a new Comet that appeared there; and he was engaged by Government to give lectures in Navigation and the Theory of Gunnery to the Indian Navy. He interested himself in the laws of probabilities, and made large numbers of experiments and observations in illustration of them.

He studied music scientifically, and at the request of the then President of the Royal Society he delivered, in 1877, a course of lectures at the Royal Institution in illustration of the application to music of the acoustical discoveries of Helmholtz. He took the degree of Doctor of Music at Oxford, and was for many years one of the Examiners at the University of London.

When he was between 30 and 40 years of age he discovered that he had the curious defect of vision called colour blindness, and in 1856 he presented to the Royal Society a paper descriptive of his case, which, on the recommendation of Sir John Herschel and Professor Stokes, was published in the Philosophical Transactions. He was elected a Fellow of the Society in 1861; he served six years on the Council, and in 1888 went to Bologna to represent the Society and the University of London at the great Octocentenary Fêtes held there.

In 1864 he was elected, without ballot, into the Athenæum Club, on the ground of scientific distinction.

Until almost the end of his long life, Dr. Pole continued to take an interest in the progress of science.

He died on Sunday, the 30th December, 1900, at his residence, 9, Stanhope Place, Hyde Park, W.

His life, crowded with useful work, performed with untiring labour and masterly ease, was a long and successful endeavour to advance and apply scientific knowledge in many fields, and was conspicuously marked by thoroughness and precision

J. W. S.

OBITUARY NOTICES

OF

FELLOWS DECEASED.

PART ii.

[*Reprinted from* 'Year-book of the Royal Society,' 1902 *and* 1903.]

SIR ANDREW CLARK, BART. 1825 (?)—1893.

The long delay which has occurred in the appearance of an obituary notice of our distinguished Fellow, Sir Andrew Clark, has been due in part to the hope that the promised volume of his biography might be available for our sketch. It has, however, not yet appeared, and we must not wait for it any longer.

Sir Andrew Clark was born in Aberdeen about the year 1825. His parents both died when he was very young. He had never known them, and, curiously, he went through life in the belief that he was a year or two younger than his real age. It is possible, indeed, that the discrepancy was greater than is suggested, for if his birth be placed in 1825 instead of 1826 (as he thought) it still makes him only 19 at the time that he obtained the diploma of the London College of Surgeons. The age of 21 is required at this College by statute. Sir Andrew died on November 6, 1893, having then, presumably, reached the age of 68 or 69. His death was caused by a stroke of apoplexy, which took him whilst in the full enjoyment of health and mental vigour. He was at the time of his death President of the Royal College of Physicians, and also of the foremost Medical Society in London—the Royal Medical and Chirurgical. To his duties in connection with these presidencies, and more especially with the first, a large share of his time and energies during the last few years of his life had been devoted.

He received his medical education partly at Dundee and in part at Edinburgh, and he held various appointments as assistant to his professors at a very early age. Soon after obtaining his diploma he

entered the Navy, and was engaged at Haslar Hospital for seven years, chiefly in pathological work. At this period of life he was in delicate health, was considered phthisical, and was sent, on leave of absence, to Madeira. At Haslar he married his first wife, whom he lost a few years later. Having been engaged chiefly in pathological and museum work at Haslar he was induced, at the age of 28, to transfer his energies to the Medical School of the London Hospital, and in the following year was elected Assistant Physician to the hospital itself.

He now commenced practice in London. It was not until ten years later that his great success came. His reputation and his practice had been slowly but steadily increasing, when, at the age of 41, he succeeded to the post of full Physician to the hospital. This at once enlarged his sphere as a teacher. In the same year the last great epidemic of cholera in London occurred, and the wards of the hospital were crowded with patients. His zeal and assiduity in connection with this outbreak and his unsparing devotion to his patients secured him the good opinion and friendship of Mrs. Gladstone, and, subsequently, of her illustrious husband. Through their influence, backed by his own sterling merits, his professional connection was soon very widely extended. At the age of 44 or 45 he removed to a commanding residence in Cavendish Square. Here he lived the whole of the remaining twenty-three years of his life, immersed in occupations which he enjoyed, but which were of the most laborious and exacting kind. He had married for the second time at the age of 33, and he left a son and daughter by his first wife, and one son and three daughters by his second.

Sir Andrew Clark was a man of most attractive personality who endeared himself to all who knew him. His love of work, his zeal in investigation, and his devotion as a teacher were unbounded. Although never really in strong health, and obliged to live strictly by rule, he could endure without obvious fatigue an amount of work which would have been impossible to most men. It was a matter of unceasing regret to him that the absorption of his time in private and hospital practice prevented him from cultivating, as he would have liked, the more strictly scientific aspects of his profession. His friends were accustomed to hear frequent expressions of his determination to relinquish practice and devote himself to investigation; the time, however, never came. So high was his estimate of the functions of a teacher, that long after his practice had become such as to demand all his time, he was most punctual in his attendance at the London Hospital, and he retained his post of physician as long as the rules of the Institution allowed him to do so.

Although Sir Andrew was not the author of any epoch-making book,

and no great discovery claims his name, yet his influence on the medical profession and on medical science was great. He had assumed the vocation of a teacher at a very early age, and in every appointment which he held he was unwearied in the lecture-theatre. His enthusiasm in his subject and his flow of appropriate language gave to his lectures a charm which always secured him a crowded and attentive audience. His gift seemed to lie rather in oral instruction than in written works, and it is precisely this kind of power which it is the most difficult to estimate. He was, moreover, a most fluent speaker, whether in lecture or conversation; but he was a fastidious writer, and did not like to permit any hasty composition to go forth under his name. The leisure for quiet composition was never his. Thus it has come about that neither our own Society's "Transactions," nor those of the medical associations with which he was connected, can boast of many papers by him. The medical journals of the day occasionally secured a lecture by the aid of a reporter, but only very seldom did anything appear which was actually written out by himself.

The subjects with which the name of Sir Andrew Clark are chiefly associated are "Fibroid Phthisis," "Renal Inadequacy," and "Catheter Fever"; but the range of his interest was unbounded. To the first volume of the "London Hospital Reports," he contributed, under the characteristic title of "Gleanings from the Field of Observation," a series of notes on very varied clinical topics.

At the time of his death, Sir Andrew was at the zenith of his fame, and was acknowledged by all as the leading physician of the Metropolis. He had throughout his career been very liberal, not only in gifts of money, but in the bestowal of his time without recompense.

Sir Andrew's portrait was painted by Mr. Frank Holl and presented to him as a gift from a large circle of friends. It is now in the National Portrait Gallery.

The new pathological theatre at the London Hospital has been inscribed to Sir Andrew Clark's memory, and it was in part built by a special fund collected in order to provide some fitting memorial of him.

It is a pleasant fact to be kept in memory by his friends that his last consultation, that during which his apoplectic seizure occurred, was a gratuitous one. He was engaged with a lady in discussing a work of charity when the call to cease from all work came to him.

J. H.

EMIL DU BOIS-REYMOND. 1818—1896.

"With intellectual leanings impelling me in almost equal degree in various directions of natural knowledge, it has been my fate as an investigator to devote my endeavours almost exclusively to a single and, apparently, quite limited province. I was 22 years old when Johannes Müller set before me the question as to the nature of Nobili's frog-current, and now, after the lapse of 34 years, I am still searching for the answer to that question."

Thus wrote du Bois-Reymond in 1875, and the search was pursued for yet another 20 years.

Born in Berlin in 1818, educated partly in Berlin, partly in Neuchâtel, he owed much to the foresight of his father, who, as du Bois himself relates, "had the goodness, in spite of his slender means, not to press his son into practical life, but enabled him to devote himself to the study of animal electricity."

At 22 years of age (1840), having completed his medical curriculum, be became Müller's assistant and embarked at once upon what proved to be his life-work. At the end of his first seven years' service (1848) the first volume of the "Untersuchungen über Thierische Elektricität" was published; in the next year the second volume appeared, breaking off, however, in the middle of a sentence, of which the concluding words did not see the light until 1884. The pause of 35 years is of itself an eloquent commentary upon the care and patience of the student, and it was a busy pause—how busy we may best realise from du Bois-Reymond's own apology and justification.

"The multiplier with its double needle was soon completely displaced by the reflecting galvanometer. Platinum electrodes in salt solution gave way to amalgamated zinc in zinc sulphate; albuminised membranes to modelling clay. Unpolarisable electrodes made it possible to map out lines of current and of potential in animal electromotors with greatly increased exactitude, and to apply exciting currents to the tissues with far less fear of fallacy. The dreaded inequalities of action at the metallic ends of the multiplier, that cost me such long hours of fruitless struggle, lost all their terror. Such slight inequalities as were still encountered were annulled by a twig of current; and by the compensation method electromotive forces came to be measured like cloth by the yard. Their exact numerical measurement took the place of rough estimations of current-strength. The aperiodic magnet not only facilitated galvanometric observations to a degree that was hardly realised outside electro-physiological laboratories, but actually brought within range many otherwise inac-

cessible questions. Not to mention the facilities afforded by various accessory instruments—keys, rheochord," &c.

And to us of the newer generation—whether we agree or disagree with the theoretical conceptions that were the impelling force of du Bois-Reymond's patient endeavours—not the least of his services have been these very real and positive achievements in the dull field of preliminary grovelling. We cannot criticise his conceptions except by means of the weapons he has himself fashioned and placed in our hands.

As every student knows, the discoveries of du Bois-Reymond are of fundamental importance; he was the first to give definite proof that active muscle undergoes chemical alteration, and that both muscle and nerve undergo alterations of their electromotive properties during physiological activity. It is certainly no exaggerated estimate of du Bois' share in the evolution of animal electricity—born 50 years before in the Casa Galvani at Bologna—to say that he has been the active hinge round which the entire subject has been turned from an empirical to a rational aspect. And we shall hardly be guilty of injustice to either his predecessors or his successors in the field if we regard the historical development of animal electricity as falling naturally into two volumes—a volume before du Bois-Reymond and a volume after du Bois-Reymond.

But this estimate of his place in Science, considerable as it is, and none the less considerable in that this "*torso*," this "*monstrum per defectum*," as he somewhat mournfully characterises the "Thierische Elektricität," never fulfilled the ideals of the young and zealous student, s the smallest part of the man himself. He was the last of the encyclopædists, yet a man of strenuous simplicity, a fervent preacher of the broad gospel of "the mother of the sciences," less to the limited circle of professed scientists than to the wide audience of thinkers, whether in science or in law or letters, that are the brain of the German body. The authoritative weight of his voice was in this respect unique, and was the outcome of a concurrence of tributary qualifications—qualifications of blood, of character, of training, of family circumstances, and of official circumstances.

Sprung from a Huguenot stock, and bred chiefly in Berlin, he was a happy blend of German thoroughness with French keenness. With four languages at command, German, French, English, and Italian, he spoke and wrote German with a clearness and elegance that—joined to the fact that whenever he spoke and wrote, he gave expression to his own mind—rendered him a writer and orator of the first rank, second indeed to none of his contemporaries. And by the influence thus acquired, he was enabled to advance the material interests of Physiology, while he contributed in no small measure to the education

of scientific taste, which in Germany as in England was wont to be silenced by the more showy claims of literature and of art. The cluster of Institutes, of which the Physiological Institute forms part, and which to-day is still among the finest in Europe, was the direct outcome of du Bois' personal influence with the Emperor of Germany; and in connection with the lecture theatre of the Institute a private box for the accommodation of royalty signifies an interest which, when not embarrassing, may be of considerable value to the advancement of science.

After 18 years' service as assistant to Müller (in 1858) du Bois-Reymond succeeded his master in the chair of Physiology. Nearly 20 years later (in 1877) the new Institute of Physiology, of which he remained the active head for a further period of nearly 20 years, was completed. Thus du Bois-Reymond's public career extends over nearly 60 years, in three periods of 20 years each—a first period as Müller's assistant, a second period as Müller' successor in the inconvenient laboratory of the old University building, a third period as Director of the palatial Institute that he had urged into existence. As a student of animal electricity, his activity was greatest during the first period, which saw the publication of the "Thierische Elektricität." During the second and third periods, his duties as Secretary of the Berlin Academy of Sciences, as Editor of the "Archiv fur (Anatomie und) Physiologie," and as President of the Physical and of the Physiological Societies, absorbed a large share of his time. From first to last the delivery of his official course of lectures on Physiology was a first charge upon his energies, and he spared neither time nor trouble to maintain these lectures at their high intellectual level. The more popular utterances to which from time to time he was bound by official usage, and which are collected in two volumes, are marked by literary excellence and broad learning. Among these essays perhaps the most important were that upon the "Limits of Natural Knowledge" (1872), concluding with his celebrated and much-criticised "Ignorabimus," and the sequel eight years later published under the title of the "Sieben Welträthsel," and concluding with the less quoted but hardly less misunderstood "Dubitemus." In these essays, du Bois-Reymond speaks to the great thinking public as the exponent of positive science, and in natural and inevitable reaction from the "vitalistic" standpoint of Müller, takes up a philosophic position of which "materialistic" is the most frequently chosen adjective. He did so in common with his three great contemporaries, Helmholtz, Brücke, and Ludwig, and with them helped to introduce into physiology further (but not final) physical and chemical analysis.

But perhaps the essay which was most striking and characteristic of the man himself in the full vigour of his maturity is the philippic

which he delivered as Rector of the University on August 3, 1870, the day before Wissembourg, and just six weeks before Sedan.

" . . . . But this Richard III is nearing his field of Bosworth, and the day is preceded by the haunted night . . . . Yet let us leave him who is but a passing shade. There is another indictment to be drawn up. Louis Napoleon has an accomplice. I do not speak of his pitiful tools, of those strangers, dukes, and chancellors who lie for him to-day as they will counter-lie against him to-morrow. The criminal whom I arraign, more dangerous than Louis Napoleon himself, because imperishable, is the whole French nation. I proclaim this aloud from the tribune of the premier German University, to be whose mouthpiece at this historical pass I prize as highest honour. I call upon the French people to hear and understand how sentence is passed upon its present state, not merely by the pens of journalists, or the gossip of boon companions, or the limited patriotism of young braves, but by the deliberate judgment of a learned body which consists of most serious, most honourable, and most impartial men—of our most distinguished German teachers and scholars. Myself of almost pure Celtic blood, half French by education, I pronounce these words with deepest pain, for the roots of my intellectual life spring in large measure from French soil. All the more do I feel it to be my right and my duty to speak as I shall speak, since my almost international position can but increase the weight of my words in the minds of all clear-thinking Frenchmen."

This war-speech gave great and enduring offence, which, however, was justified less by the general tenor of the speech, which was at the same time severe and respectful, than by the partial and twisted quotations of it that appeared in the Paris journals. Du Bois-Reymond, Rector of the University of Berlin, knew and appreciated better than most men the strengths and weaknesses of the French nature. And in that sense, although a Berliner, he was a good Frenchman, just as, although bearing a French name, he was a good German.

Among the biographical essays from du Bois-Reymond's pen two in particular have permanent historical value and interest, the first dealing with the career of Johannes Müller, the last—which was also the last act of his life—giving us a most living and dramatic picture of his great fellow-student Helmholtz. Thus it fell to du Bois-Reymond to turn the first and the last pages of what will in time to come stand out as one of the most vigorous chapters in the life-history of physiology, the second half of the nineteenth century, a period deeply scored by the names of four great men—Ernst Brücke, Karl Ludwig, Hermann Helmholtz, Emil du Bois-Reymond.

A. D. W.

Sir GEORGE HUMPHRY. 1820—1896.

Sir George Murray Humphry was born at Sudbury, in 1820, of a family of some distinction in Theology, Law and Medicine. He died September 24, 1896. At the age of 16 he was apprenticed to Mr. Crosse of Norwich. In 1839, he went to St. Bartholomew's, where he won the gold medal in Anatomy. In 1840, he won the gold medal of the London University for Anatomy and Physiology; and honours in Chemistry. At the age of 22 he was recommended by James Paget to George Paget for a vacancy on the Honorary Staff of the Addenbrooke's Hospital, and in due course he became a graduate of the University in which he was afterwards to play a considerable part. One of his first steps was, in conjunction with George Paget, to obtain leave to give clinical lectures at the Hospital. In 1847, Professor Clark deputed to Humphry the part of Human Anatomy in his course, and from the beginning his lectures attracted attention for their breadth and lucidity. In 1866, sixteen years after Humphry's arrival at Cambridge, Clark resigned the Chair of Anatomy, and a Chair of Human Anatomy was founded separately; to this chair Humphry was elected, and for seventeen years he held it with great distinction. Being then desirous of resigning the teaching of anatomy, which under his hands had grown into a very large department, a Chair of Surgery was founded, without stipend and terminable at his death, in order to do him honour as one of the leaders in the reform of the Faculty of Medicine in Cambridge; and in recognition of his remarkable powers, both as a teacher in the School of Anatomy and as a skilful and enthusiastic clinical surgeon. In 1891 he received the honour of knighthood.

As an anatomist, and especially as a surgical anatomist, his perseverance and devotion were such as distinguish only the greatest men of his calling. This is not the place to tell any of the stories current among his old pupils of the keenness, resourcefulness and indefatigable tenacity with which he would follow up a case which had interested him; and he rarely missed his reward, and the enrichment of science, in the addition of some material record of it to the Museum of Surgical Anatomy, which henceforth will be known by his name. Thus it was that perhaps no surgeon of his time, unless it were James Paget, had so great a wealth of experience on which to draw for the illustration of surgery. Yet by this wealth he was never embarrassed in his teaching; dogmatic enough to fix the attention of the student, he was yet so full of life and play of thought that the student was as much interested in the processes

of his thought as in the results expounded. Moreover, a facility of expression, of epigrammatic point, and of pertinent illustration, gave a vividness to his lectures which none of his pupils forget. Of no clinical teacher, perhaps, are so many "sayings" still quoted. In presence he was no less remarkable; it is hard now to imagine the streets of Cambridge without a vision of that keen face and slender frame, worn, as it were, by incessant activity of mind and body. In private life his influence was no less attractive; closely occupied as he was by his profession, he retained, nevertheless, to the end of his life, a curiosity and openness of mind towards all and any subjects of scientific or literary interest, which made him a stimulating and interesting companion. The subtlety of his mind indeed, and a certain defect in judgment of individual character which is common in men of his masterful and eager nature, laid him open sometimes, especially in his earlier days, to strong and even bitter opposition. With Paget and Michael Foster, Humphry had a leading part to play in the resurrection, or indeed the creation, of the Medical Faculty as a great department in Cambridge; to this end his masterfulness of character was essential, and, if at times his subtlety and pertinacity were resented, his courtesy and vivacity of manners, his humour and persuasiveness as a public speaker, the purity of his motives, the loftiness of his purpose, and his attractive personal qualities, at any rate in his later years, disarmed all opposition and animosity. Of his contributions to medicine, reference may be made to his book on "Old Age," published in 1889; and to the article on 'Tetanus' in Allbutt's "System of Medicine," written shortly before his death.

It is, however, upon his contributions to Anatomical Science, which were numerous and valuable, that Humphry's scientific reputation chiefly depends. His first and largest work, "The Human Skeleton," published in 1858, was a record of original observation and research; indeed in its day it was the most remarkable book on the subject, and on almost every page it shows the care and pains that had been expended in its production. He was one of the first to observe that the cancelli in each bone show a definite arrangement of their lamellæ, and to point out the practical importance of this in the mechanics of the skeleton. His tables showing the relative lengths of the long bones in different races, embodying much laborious work done by himself, were the earliest researches in this branch of physical anthropology.

In the department of Muscular Anatomy he published an important series of descriptive papers, the records of his dissections of animals; and from this ontological material deduced certain general principles in muscle-morphology. His results are interesting; as in some

respects, such as the mode of delamination of the somatic musculature, he was led to conclusions which have been confirmed on other grounds. His morphological views, both in the study of the bones and muscles, were based on ontology rather than on embryology; and his views on homology were largely, though not slavishly, founded on those of Owen.

The furtherance of Anatomical Science always occupied a prominent place in his thoughts: in 1866 he had, in connection with Sir W. Turner, started the "Journal of Anatomy and Physiology," of which for some years he was an active editor. About twenty years later he took a leading part in the organisation of the Anatomical Society, of which he was the first President.

It should be remembered that all this work was done while he was engaged in a large and laborious practice in the Eastern Counties. Yet even to the last his interest in the advancement of anatomical science never flagged. He had lively memories of the way in which the importance of anatomy had been impressed upon him at the threshold of his professional study by his master, Crosse, of Norwich, who had himself been in his youth a favourite pupil of Macartney, and afterwards a demonstrator in the Dublin School before he settled in Norwich. It was, therefore, with a sort of filial affection that Humphry regarded the Macartney specimens which formed the greater part of the Cambridge Museum when he became Professor in the University.

T. C. A.

SIR JOHN BUCKNILL. 1817—1897.

John Charles Bucknill was born at Market Bosworth in 1817, and died at Bournemouth in 1897. He was educated at Market Bosworth, Rugby, and University College, London, where he graduated with honours, 1840, first in Surgery, third in Medicine, Fellow in 1850, Council in 1884, benefactor at death; Lic. Soc. of Apothecaries, 1840; M.R.C.S., 1840; Lic. Royal College Physicians, 1853; Fellow, 1859; Council, 1877; Censor, 1879; Lumleian Lecturer, 1878; Fellow Royal Society, 1866; knighted, 1894. He commenced his career as House Surgeon, University College, London; thence he entered upon a small practice near Eaton Square, wherefrom the London fogs banished him to the Superintendency of the Devon Co. Lunatic Asylum. Here he worked with good effect and made his mark both as an experimentalist and a writer, which latter experience led him to start and edit the "Asylum Journal," now

entitled the "Journal of Mental Science." He also wrote, conjointly with Dr. Hack Tuke, the "Manual of Psychological Medicine;" which held the field as a text-book for many years, and passed through several editions. Among other of his works may be noted his many critical essays on Shakespeare's psychological and medical knowledge, collected into two books; his works on habitual drunkards and on criminal lunatics and their treatment. He carried on Conolly's great reforms whereby lunatics became emancipated from the fearful thraldom of former days.

He was a keen sportsman and was mainly instrumental in starting the Exeter and South Devon Volunteers, in 1852; the enrolment of which regiment Lord Palmerston subsequently specially mentioned in Parliament as the inception of the present Volunteer movement.

In 1862, he became one of the first trio of Visitors of Chancery Lunatics and so remained for 14 years.

T. C. A.

C. S. ROY. 1854—1897.

Charles Smart Roy was a native of Arbroath. He was educated in that town; then at St. Andrews, and then in the University of Edinburgh. At Edinburgh he graduated in medicine in 1875, and was subsequently appointed a resident physician at the Royal Infirmary in the wards of Dr. Balfour, well known as an authority on valvular lesions of the heart. On completion of the term of that office Roy moved to London, and there engaged in research work on the contagious pleuro-pneumonia of cattle. However, on the outbreak of the Turko-Servian war he volunteered for service. As Surgeon-Major in the Turkish Army he was given charge of the garrison hospital at Yanina in Epirus. Epirus remained untouched by the active fighting of the campaign, and during his garrison leisure Roy designed an instrument for recording changes in the volume of the frog's heart—his frog cardiometer.

At close of the war he returned to London, and finished his investigation into pleuro-pneumonia, conducting it at the Brown Institution. This work is the only one by him that deals mainly with anatomy. He proceeded next to Berlin. At Berlin he studied pathology in Virchow's Laboratory; but he also began, in Du Bois-Reymond's Institute, an investigation into the physiology of the heart, chiefly with use of the cardiometer above alluded to. He was thus one of the earliest workers in Du Bois' new Physiological Institute, where Professor Kronecker was then chief assistant. He proceeded

to his M.D. degree in 1878, and in that year his paper, "On the Influences which Modify the Work of the Heart," was published in Foster's *Journal of Physiology*—a paper based chiefly on the research done in Berlin.

In the course of the next year Roy went as assistant to the Physiological Institute of the Strassburg University, under Prof. Goltz. There he was allowed to devote his time almost wholly to research. Thence came "Observations on the Form of the Pulse-Wave as Studied in the Carotid of the Rabbit"—a paper showing more clearly than any of his previous the advent of an investigator of originality and great experimental skill. An instrument was devised for the research—the sphygmotonometer—a kind of plethysmograph, adapted to record the changing volume of the free but unopened blood-vessel. Original tracings obtained in this research hang now in not a few laboratories both at home and abroad. It was at Strassburg that Roy devised his instruments for measuring the extensibility and elasticity of the walls of blood-vessels. This latter subject was dealt with by him in a paper appearing in Foster's *Journal* in 1879. His instrument had points of resemblance with the Holmgren-Blix myographion, but preceded it, and was invented altogether independently of it. In the same year was published, also in Foster's *Journal*, his work with Dr. Graham Brown of Edinburgh, on capillary blood pressure. The research furnished more trustworthy measurements than any pre-existing of the kind. They provided data, until then almost wanting, regarding one of the most important factors in the circulation. The method employed was extremely ingenious, and for its object has never been surpassed in accuracy.

Roy now moved from the Physiological to the Pathological Laboratory at Strassburg; both buildings were then close together in the old École de Médecine, near the Spital Thor. He, however, found v. Recklinghausen's laboratory occupied so exclusively in the anatomical aspect of disease that he soon migrated to Leipzig, attracted thither by the teaching of Cohnheim. There, in personal contact with Cohnheim, his attention was directed to problems regarding the renal circulation. He invented the instrument by which his name is best known—the renal oncometer—for the study of variations of the blood-flow through the kidney. The instrument is now familiar to every physiologist and pathologist. With it Roy and Cohnheim prosecuted a research which remains a classic to students of the circulation. The acquaintance of the two workers rapidly ripened into close friendship. The late Prof. Kühne, in his memorial sketch of Cohnheim (1885) prefixed to the *Gesammelte Abhandlungen*, wrote: "These exact and laborious researches, through

which the younger worker and the elder will go down to posterity together, were the last that Cohnheim himself ever entered upon. During their prosecution it was a delight to him to admire the wonderful skill and easy dexterity of his younger colleague; he saw that those gifts were well suited to advance scientific pathology in the very direction in which he himself believed it could prosper best." Cohnheim's death in 1884, at the early age of forty-five, was felt by Roy as a severe personal loss. He often spoke of Cohnheim in terms of enthusiastic admiration. He looked upon himself as in a way representing in this country the leadership which Cohnheim held in the new school of pathology in Germany. Roy stayed at Leipzig nearly a year. While there he received the "George Henry Lewes Studentship" for research in physiology, founded by "George Eliot." He was its first recipient.

In tenure of this studentship he worked in Prof. Michael Foster's laboratory at Cambridge. Thence he issued his paper, "On the Physiology and Pathology of the Spleen." This communication contains his discovery of an autochthonous rhythmic tonicity in the mammalian spleen; the vasomoter reactions of the organ were also elucidated. In 1882 Roy was appointed Professor Superintendent of the Brown Institution. There he plunged into the work on the actions of the mammalian heart, work which he never relinquished until nervous breakdown divorced him from all laboratory cares.

In the year 1884 Roy was elected to the Fellowship of the Society, and very shortly afterwards he was appointed to the newly-established Chair of Pathology in the University of Cambridge. He was then in his thirtieth year. Although his activity at Cambridge during his later tenure of the chair suffered under his failure in health, and in the early period was hampered by want of accommodation in the matter of laboratory room and equipment, Roy's work for pathology in the University, for the short time that it had free scope, was marked by conspicuous success in many ways. In 1887 he succeeded in securing the foundation for pathology of the J. Lucas Walker Studentships. The selection of these students lay largely with him, and in his laboratory the main part or the whole of their work was accomplished. The recital of their names—J. G. Adami, W. Hunter, Alfred Kanthack, Lorrain Smith, W. Wesbrook, Louis Cobbett—suffices to indicate the sterling value of Roy's judgment and discretion in this part of his office.

In 1889 buildings vacated by the Chemistry School were transformed and refitted to receive the department of Pathology. From the better laboratory proceeded a rapid output of excellent work in experimental pathology; researches on endocardial pressures, on the relation between heart beat and pulse wave, on the mechanism of the

circulation in the brain, on the specific gravity of the blood, on the causation of "shock," on mechanisms protective against infection, on the seat of the formation of hæmoglobin, on phagocytosis; in all these he was, if not the initiative spirit, a participant and adviser, evincing always the keenest and most sympathetic interest. His interest in biology was strikingly catholic, but problems dealing with the circulation had paramount attraction for him. Encouragement to devote attention to the clinical aspect of that field was given him by his colleague, Clifford Allbutt, the Regius Professor of Physic. In 1892 appeared, in the "Philosophical Transactions," the long work on the mammalian heart carried out with Professor Adami. Instruments were to a large extent specially devised for this research. The cardiac plethysmograph and the cardio-myograph were each examples of ingenuity that never failed to meet with resource the mechanical difficulties of a subject numerously beset by them.

Roy entered upon pathology at a time when advance in bacteriological methods was opening to it new fields for investigation in regard to the diseases of infection and their remedy. He welcomed this new line of inquiry with characteristic readiness, and at once felt its coming value. But the somewhat monotonous kind of labour involved in this class of investigation was tedious to him to a degree unexperienced by less rapid and less impulsive workers. He, however, contributed to such investigations. When Professor Superintendent of the Brown Institution he was commissioned to investigate in the Argentine Republic a disease which was devastating the herds in the province of Entre Rios. He succeeded in devising a preventive inoculation which alleviated the mischief. In 1885, Asiatic cholera having appeared in a very severe epidemic form in Spain, he, with Graham-Brown and Sherrington, investigated the bacteriology of the epidemic throughout the summer and autumn of that year. The work was one of the earlier confirmations of Professor Koch's discovery of the cholera-spirillum as the concomitant of the disease. In evidence of his sterling enthusiasm for this branch of his science, it may be recalled that Roy was one of the earliest, perhaps the earliest, to start and urge forward the movement which has resulted in the foundation of the "Jenner Institute."

His death at the early age of forty-three came somewhat suddenly, though after complete nervous breakdown had for three years removed him from scientific work. In 1887 he married Violet, daughter of Sir George Paget, the late Regius Professor of Physic at Cambridge.

A man of strong convictions, almost impetuous in his determination to act upon them, Roy as a pathologist had the firm belief that the future of pathology lay along the same lines of advance as physiology

has followed with success. The inferences to be drawn from mere anatomical study of structural changes induced by disease he considered to have been for the time being practically exhausted. Indeed he thought much toil had been wasted in pushing such observation into confines of hair-splitting minuteness. Not that he took little interest in microscopy. New methods of staining tissues, of colouring bacteria, and of following the appearances of cell-life appealed to him strongly, and he was early to follow them. It was rather that the laborious unravelling of an individual autopsy by prolonged anatomical search and argument seemed to him unfruitful, and he gave little time to it. He looked for inspiration to physical and chemical and physiological methods. He declared the relative paucity of the British contribution to pathological discovery in his own and the preceding generation due to allotment of an excessive time in the medical schools to mere dissecting-room work. He maintained that this rather closed than opened the mind for the broad problems of medicine, and that in addition it left the student unequipped for scientific lines of research. His own ingenuity in devising and his skill in using mechanical apparatus might be termed, as Kühne expressed it, quite "extraordinary." It was to a certain extent harmful to the quality of his work: it limited the scope with which he undertook and the depth to which he pursued a subject; it continually tempted him to wander from investigations towards which he had already accomplished the preliminaries to open fresh ground in some other direction. A plan usual with him in his own work was to set before himself some particular measurement, *e.g.*, the change in volume of an organ under certain conditions; the more difficult the experiment the more attraction it had for him; he devised appropriate apparatus, tried it, altered it, made it successful, obtained a limited number of complete observations, and then moved to another problem often not cognate with that previously taken up. As an operator in the laboratory he had no equal in this country. His scientific papers were all written in a brief, simple, and direct style, without repetition of statement, almost always with exclusion of all protocols of experiments, and usually without even any final recapitulation.

As a teacher his career commenced and ended at Cambridge. His lectures, especially those on the circulation, were effective mainly by their striking originality. In the students who attended his classes for ordinary examination purposes he took curiously little interest; whether they passed or failed, attended or did not attend, seemed to go quite unnoted by him. To those who came to pursue research, even of the most unambitious kind, he was a different man. To these he gave time and thought unstintingly. He treated them

almost forthwith as personal friends, and he attached them to him by many ties of kindness and respect. In regard to their work he was always interested, always sympathetic, equally so in failure and success, and always ready to throw all his knowledge and resource, and on many occasions hours upon hours of work, into overcoming the difficulties their experiments encountered.

Professor Roy was of middle height, strongly built, and naturally very resistant to fatigue. He was of ruddy complexion. He became quite prematurely grey. A feature of his character was physical courage amounting to enjoyment of personal danger. Among his pastimes were boating and riding. The flight of birds, the possibility of aerial flight by man, and the construction of flying machines formed a favourite theme of conversation with him; and he had made some experiments upon the subject.

C. S. S.

Sir JAMES PAGET, Bart. 1814—1900.

The career of Sir James Paget, which was closed by his death in January, 1900, had been one of the utmost advantage to medicine. Not only had he by innumerable observations on disease enriched with new and valuable possessions the special department of clinical surgery, but by his unwearied devotion to science in general, and to the cause of education, he had earned the gratitude not alone of all classes of the profession to which he belonged, but of the nation into which his lot was cast. He died full of years and of honours. Although he had for some time been more or less disabled by illness, he had continued his labours for the public good up to the last sitting of the Royal Commission on Vaccination. He signed the Report of this Commission, and it was probably the last of the more important acts of his life. A form of aggressive muscular paralysis was at that time threatening him, and its steady progress not long afterwards deprived him of the use of his limbs. His intellect was unclouded to the last; nor, excepting that it incapitated him from most of the enjoyments of life, was his illness attended by pain. He was within a few days of his 86th year when he passed peacefully away, free, as one of his sons has written, "from even the least pain or trouble of mind or body."

Sir James was of Norfolk family and was born at Great Yarmouth, in 1814, being one of a large family. His only education was that of a school in his native town, but as such it was good, and it was supplemented by the influence of highly intelligent parents. Having

served an apprenticeship of nearly five years, under favourable conditions, in the same town, at the age of 21 he came to London, and was entered as a pupil at St. Bartholomew's Hospital. Before leaving Yarmouth he had taught himself French, and had read largely both in medicine and natural history. He was a trained botanist, and in conjunction with a brother had already published a Natural History of Great Yarmouth, devoted, we believe, chiefly to its flora. His elder brother, George, afterwards Sir George, had been at St. Bartholomew's before him. During his first year he was fortunate enough to discover in the dissecting-room subject the Trichina spiralis, concerning which he wrote a very complete account. He obtained his diploma at the College of Surgeons in 1836, having previously distinguished himself as a prize winner in the Hospital Classes. Then followed several years of laborious work in London, during which Paget supported himself by medico-literary work, by coaching students, and by a very small stipend as Curator of the Museum of St. Bartholomew's. In 1839 he narrowly escaped death from typhus fever. Soon after this his career as a teacher began by his appointment as Demonstrator of Morbid Anatomy, and in 1843 he was appointed Warden of the newly established College for resident students at his hospital. This office enabled him to crown a long engagement by marriage to one who proved a most devoted helpmate almost to the conclusion of their long united life. Lady Paget predeceased her husband by only a few years.

Paget's demonstrations were from the first exceedingly popular with the hospital students and he early secured the good opinion of some of the senior members of the staff, more especially of Mr. Lawrence and Mr. Stanley. The latter was his enthusiastic admirer and friend. With him, in 1842, Paget undertook the preparation of a catalogue of the specimens in the Museum of the Royal College of Surgeons. This was a work involving enormous labour, and it was completed in a way which constituted the resulting volumes a model for all similar undertakings. It was not till 1847, when he was 33 years old, that Paget secured his first step on the surgical staff of St. Bartholomew's. Four years later he resigned his Wardenship on account of the increasing claims of private practice, and from this time onward his success was rapid. He resigned the appointment of full Surgeon to St. Bartholomew's in 1871, having held it ten years. As early as 1858 he had been appointed Surgeon-Extraordinary to the Queen, and in 1871 he was made a baronet. In 1874 he became President of the College of Surgeons, having been for long a member of its Council, although he had never accepted the office of Examiner. In 1876 he was elected representative of the College on the General Medical Council, being at the time President of the Royal Medical and

Chirurgical Society. At the age of 73 such was his youthful energy and zeal that he did not consider himself too old to accept the post of President of the Pathological Society.

It would be tedious to attempt to enumerate in further detail the honourable appointments which from year to year he undertook, or the honours which were conferred upon him. He was a member in succession of several Royal Commissions, and Vice-Chancellor of the London University.

Our estimate of the influence which Paget exercised on the destinies of his profession must not be restricted to any work which bears his name. In countless committees, not a few councils, and several important commissions his was a guiding voice; innumerable were the resolutions, recommendations, and reports which he originated. His calm, clear judgment was always recognised; and whatever he said was sure to be received with the utmost attention by all, and by the majority with acquiescence. Seldom, indeed, was his vote given in the minority, but more often than not it was his speech which had decided the conclusion. The writer sat with him many years in the Council of the Royal College of Surgeons, in the meetings of the Committee on Leprosy originated by the Prince of Wales, and through two long Royal Commissions, and had abundant opportunities for appreciating his almost unerring skill in the mastery of facts and his unequalled facility in expressing the opinions at which he had arrived.

There is yet another department of silent influence which should be mentioned. Few men had exercised a wider power than he in the nomination of younger men to posts of importance. He was consulted by public bodies on all hands, his appreciation of character was excellent, and his suggestions were always judicious. Not a few of those who in various places now hold high positions in the profession were in their early career his nominees.

As a practical surgeon the qualities which Paget brought to his patients' help were cool nerves, keen observation, clear judgment, and wide experience. At the hospital his diagnosis was highly valued by all his colleagues. At a later period in his career, during the quarter of a century of his most active practice, his verdicts were regarded as well-nigh conclusive by the whole British profession.

As an operator he was at no time showy, but at all times safe. He always did what he had set himself to do with unflinching regard to his patients' interests.

Perhaps it might be said that sobriety of mind was the distinguishing feature in Paget's character. He was never excited and never below par, but always in full possession of the same clear intelligence and capacity for open-eyed observation. Never for a moment

did his wits fail him, either as regards what ought to be said or the best words in which to say it. His handwriting might perhaps be quoted in illustration of his unfailing balance. It was always, whether written in haste or at leisure and regardless of varying qualities in pen and paper, exactly the same. Readiness of reply and aptness at repartee may probably be taken as good evidence of this most enviable presence of mind. Many good things might be related of Paget in this direction.

It is perhaps in some place between John Hunter and Sir Benjamin Brodie that we should find a niche for Paget. His enthusiasm for Hunter and his methods of thought and work was unbounded; and although not a great collector himself, it was because the need for that kind of work had to some extent passed, rather than from want of zeal. His industry as a museum expounder was proved by the production of his *opus magnum*, the Catalogue of the Pathological Part of the Hunterian Collection. Until his time was absorbed by private practice and public committees he was indefatigable in microscopic research. Yet in his relations to the profession and the public, as, having been for a long series of years the acknowledged head of the surgical calling in Great Britain and Ireland, he more nearly trod in the steps of Brodie than of Hunter, and between these two a very interesting parallel might be drawn.

As some proof of his success as an observer it may be noted that no fewer than three different maladies have become known by his name. Leaving aside the Trichina spiralis, we have Paget's Osteitis deformans and Paget's nipple cancer.

It would be unpardonable in any sketch of Sir James Paget's character and attainments not to make special mention of his skill as an orator. At the same time it must be insisted that his success in this direction was in the main due to the fact that he had always something to say which was worth saying, and that he always knew exactly what it was that he wished to say. It was no mere skill in the arrangement of words which gave a charm to all that he uttered in public. The manner was, it is true, something, but the matter was far more. His renown as an after-dinner speaker was probably second to that of no one during the years of his prime. Nor were his more formal public addresses less successful. The latter were, it is believed, always very carefully prepared, but many were the occasions on which an impromptu speech gave proof that such preparation was by no means essential. His sentences were always remarkable for their clearness, and they were never laboured or ornate. He paid no fulsome compliments, he told no anecdotes, he never indulged in quotations. His language was always his own, and it was its singular appropriateness to the subject, together with an inimitable air of

spontaneity and ease, which made it so pleasant to listen to. His fame as a speaker began with his earliest lectures to the students of St. Bartholomew's, and it continued to gather force through the whole of his life. The same qualities which distinguished his *viva-voce* efforts are observable also in his writing. His papers in the Medico-Chirurgical Society's Transactions are models of what such compositions should be, not alone in completeness of detail but in clearness of statement.

J. H.

HENRY HENNESSY. 1826—1901.

Professor Henry Hennessy was the second son of John Hennessy, of Ballyhenessy, and was born March the 19th, 1826, at Cork. He received at school an excellent education in classics, modern languages, and mathematics. His profession was originally that of a civil engineer, but he devoted such time as he could spare from professional employment chiefly to mathematical investigations. His contributions to science number some eighty or more original papers contributed to the "Philosophical Transactions" and "Proceedings" of the Royal Society, to the "Comptes Rendus," and to the Royal Irish Academy. In 1845, in an article published in the "Philosophical Magazine," he proposed to apply photography to the registration of the thermometer and barometer in meteorological observations, and was apparently the first to discern the importance of such records. In 1851 he contributed to the "Philosophical Transactions" his "Researches in Terrestrial Physics," dealing with the figure and primitive formation of the earth and planets. He maintained the view of the fluid origin of these forms, and showed that all the facts concerning the earth which come under our notice are best explained by the existence of fluid matter at a high temperature enclosed within its crust. He wrote on climate (British Association Reports, 1857), and claimed to have proved the existence of laws regulating the distribution of temperature in islands, and to have deduced consequences of general application from the physical properties of water. The gist of his arguments is contained in a paper in the "Proceedings," 1857–59, "On the Influence of the Gulf Stream on the Winters of the British Isles." This led, in 1870, to his being called upon to report on the temperature of waters surrounding the British Isles, for the information of a committee of enquiry into Irish Fisheries. He advocated a great extension of inland river and canal navigation. He also proposed a decimal system of

weights and measures, based upon the length of the earth's polar axis, a quantity which is capable of more accurate determination than the earth's quadrant. Standards, such as the polar foot and the polar pound, with a complete series of weights and measures on the polar system, are contained in the Museum of the Royal College of Science, Dublin. There are also, in the same collection, many ingenious models and inventions designed by Professor Hennessy to illustrate various principles, chiefly in mechanism, but also in matters touching civil engineering, such as, for instance, the form and structure of sewers best adapted to the purpose of obtaining the greatest scour, with due provision for a great influx of storm water. ("Hydraulic Problems on the Cross-sections of Pipes and Channels." 'Proc.,' 1888.) There are also models illustrating the geometrical construction of the cell of the honey bee, which was the subject of three short communications published in the "Proceedings," 1885 to 1887.

In 1855, on the invitation of Cardinal Newman, he accepted the appointment of Professor of Physics in the Roman Catholic University of Ireland, and, in 1874, he became the Professor of Applied Mathematics in the Royal College of Science.

On several occasions he delivered admirable addresses and lectures on university education in its relation to the study of science as a branch of human knowledge, as well also in its applications to the Arts and Manufactures, or what is now generally known as Technical Education. On this subject his opinions were thoroughly sound, and worthy of much greater respect and attention than they actually received at that time. To those who personally evinced an interest in his work he was always pleased to explain his views, and the use of his models. This he did with much lucidity and a remarkable modesty of manner. The writer cannot easily forget the feeling of admiration he experienced for his literary ability when, at a meeting, now many years ago, a long official letter was read, and during the progress of an ensuing discussion Professor Hennessy, on the instant, wrote in detail a complete and lengthy reply, which, without erasure or alteration of a single word, presented the views of nimself and colleagues so clearly and cogently that it was at once adopted.

During the College Session of 1890–91 he was called on, under the then recently-made Treasury rules applicable to clerical and administrative officials in the Civil Service, to retire from the Chair of Applied Mathematics which he had filled with such distinction, and, as no intimation that such a course of action was intended had been communicated to them, a great surprise fell upon some of his colleagues when they became aware, during the Christmas vacation, from persons wholly unconnected with the College, not only that he

had actually gone from among them, but that a successor had been appointed for the immediate discharge of professorial duties. Although reticent on the matter, there is no doubt he experienced a very grievous disappointment at having to withdraw his services after so many years of earnest devotion to the cause of public education, and that too under conditions of peculiar hardship to which no other class of members of the Civil Service are subjected. A memorial on his behalf, signed by the President and a large number of Fellows of the Royal Society, and Professors in the principal Universities of the United Kingdom, was presented to the Government, but without effect. He had to spend the remainder of his days in retirement on a small pension entirely inadequate in amount, especially considering the services he had rendered. He resided abroad for some time, but, under medical advice, returned to Ireland, and died at Bray, co. Wicklow, on the 8th of March last. It is much to be regretted that his widow is but slenderly provided for out of the savings put by from the small income attached to his professorship. In the estimation of his colleagues his personal character was that of an amiable, courteous, and high-minded gentleman.

W. N. H.

CHARLES HERMITE. 1822—1901.

Charles Hermite, the distinguished French mathematician, was born at Dieuze, in Lorraine, on December 24, 1822. His education was begun at Nancy, and was continued at Paris, where the marked mathematical powers of the youth greatly impressed the professor* in the Collége Louis-le-Grand.

Hermite's first memoir belongs to 1842, the greater part of that year being spent in preparing for entrance into the École Polytechnique. Some idea of his attainments and his ability may be gathered from the fact that, immediately after entering, and on the advice of Liouville, he wrote (in January, 1843) to Jacobi submitting some theorems which he had obtained relating to hyper elliptic functions; and in the succeeding year, he similarly submitted some results in elliptic functions. This work was deemed of high value by the older mathematician, who caused the letters to be printed in "Crelle's Journal,"† together with an encouraging reply of his own, concluding with the words: "Ne soyez pas faché, monsieur, si quelques-unes de vos découvertes se sont rencontrées avec mes anciennes recherches.

* M. Richard, who had had Galois for one of his pupils fifteen years earlier.

† Vol. 32. See also Jacobi's "Ges. Werke," vol. 2, pp. 87—130.

Comme vous dûtes commencer par où je finis, il y a nécessairement une petite sphère de contact. Dans la suite, si vous m'honorez de vos communications, je n'aurai qu'à apprendre."

The talent that Hermite showed during his course at the École Polytechnique indicated mathematics as his obvious career. He passed through the usual initial stages until, in 1862, he was appointed to a post specially created for him on the initiative of Pasteur. This post he held until 1869, when he succeeded Duhamel as professor of higher algebra at the Sorbonne, and as professor of analysis at the École Polytechnique. The latter chair he occupied only until 1876; he continued the former until 1897, when he retired from active teaching. His life appears to have passed in a quiet round, devoid of events of general external interest; but its influence was indicated by the character of the formal celebration of his seventieth birthday, when he was presented by pupils and a host of friends and admirers from all countries with a medal struck for the occasion.

Hermite had been elected a member of the Académie des Sciences in 1856, in succession to Binet. He became a Foreign Member of our Society in 1873; at the time of his death, there was only one Foreign Member senior to him. He was made an honorary member or a foreign associate of many (perhaps of most) of the learned societies of the world. In recognition of his discoveries, he had received a number of decorations from various countries: thus he was numbered among the knights of the Prussian "Ordre pour le Mérite."

He died in Paris on the 14th of January, 1901. The words of Jordan, Darboux, Appell, Painlevé, and others, were an indication, not merely of the loss to science, but also of the sense of personal loss to friends which was caused by his death.*

He wrote nearly 200 papers, which have been published in a great variety of places.† Many of these papers appear in the guise of letters to mathematical friends, a form of communication which he practised through his whole life.

In addition, his lectures at the École Polytechnique were published (in book form) in 1873: his lectures at the Sorbonne were published (in lithographed form) first in 1882, and they have now reached the fourth edition. Also he appended, to the 1894 edition of Serret's 'Differential and Integral Calculus,' a "Note on the Theory of Elliptic

* The writer of this notice wishes to acknowledge his indebtness to an article by M. Émile Picard, "L'Œuvre scientifique de Charles Hermite," 'Ann. de l'Éc. Normale,' 3e sér., vol. 18 (1901), pp. 9—34. There is also a brief notice by M. Jordan in "Liouville's Journal," 5e sér., vol. 7 (1901), pp. 91—95; and a sketch, together with a bibliography of Hermite's writings, is given by M. P. Mansion in the "Revue des Questions Scientifiques," 2e sér., vol. 19 (1901), pp. 353—396.

† It is understood that his works will be published in a collected edition by Gauthier-Villars, to be edited by Picard, who is Hermite's son-in-law.

Functions," which in the course of 160 pages gives an admirable outline of that theory.

As is shown by the list of his papers, Hermite wrote on many topics within the range of analysis: the subjects which recur most frequently are the theory of numbers, invariants and covariants, definite integrals, theory of functions, theory of equations, and elliptic functions. If special mention may be made of advances that are due to him, and of substantial discoveries achieved by him, instances can be selected from each of those subjects.

Thus, in the theory of numbers, he connected the use of continuous variables with quadratic forms: and he introduced conjugate indeterminates into the discussion of those forms. Perhaps the most wonderful of all his researches in this region was his proof (1873) of the transcendence of e, the base of the exponential function—a proof which, duly modified, led Lindemann to the establishment of the transcendence of π, and so showed the quadrature of a circle to be impossible.

In the theory of invariants and covariants, where he was a fellow-worker with Cayley and Sylvester, Hermite had an important share. He was responsible for the law of reciprocity whereby, to every covariant of degree n in the coefficients of a quantic of order m, there corresponds a covariant of degree m in the coefficients of a quantic of order n. He discovered the skew invariant of the quintic, which was the first example of any skew invariant. He discovered the linear covariants belonging to quantics of odd order greater than 3, and he applied them to obtain the typical expression of the quantic in which the coefficients are invariants. He also invented the associated covariants of a quantic; these constitute the simplest set of algebraically complete systems as distinguished from systems that are linearly complete.

In the theory of functions, it is almost difficult to select representative instances from among his many contributions to that subject, in which he may be regarded as the foremost of French writers since Cauchy. Not the least important are the special advances he made in the transformation of the double theta-functions and the associated Abelian functions: his memoir has been the suggestive starting-point for many other investigations. Anyone acquainted with the progress of the subject in the last 30 or 40 years will recognise that Hermite has given an entirely new significance to the use of definite integrals in the theory of functions: it is enough merely to mention the developments of the properties of the gamma-function which have been thus initiated. Indeed, he seems to have been the one mathematician of the later half of the nineteenth century who could work easily with definite integrals, almost recalling the fruitful activity of Euler in the

same medium, but with an accuracy and a precision that were impossible in Euler's day.

The theory of elliptic functions, on the Jacobian rather than on the Weierstrassian basis, is selected by Picard as having been Hermite's favourite study; and the selection appears justified by the number of his papers on the subject. To him is due the reduction of an elliptic integral to its canonical form by means of the syzygy among the concomitants of a binary quartic. His investigations on modular functions and modular equations are of the highest importance. It was Hermite who discovered pseudo-periodic functions of the second kind, and developed their properties. In a memoir that may be fairly described as classical,* he applied these functions to the integration of the unspecialised form of Lamé's differential equation; and elliptic functions generally were applied in that memoir to obtain the solution of a number of physical problems.

In the theory of equations, there are two significant contributions which will be specially associated with his name. One of these is the form which he gave to Tschirnhausen's transformation, with its accompanying property of securing invariance for the transformed equation; he also applied it to obtain invariantive criteria for the reality of the roots of a quintic equation. The other of the contributions indicated is the actual solution of the quintic equation by means of modular functions; in this result of supreme importance he was followed by Kronecker and Brioschi.

One quality of his papers deserve notice: it is the singular clearness with which they are written. It is a commonplace to refer to style as a characteristic of French writers; but mathematical investigations do not always lend themselves to clear and finished exposition. Hermite's papers are remarkable for this quality.

This brief sketch may be sufficient to give a slight indication of the range of activity of Hermite's genius. His interest in mathematics remained undiminished to the last. For many years he had been regarded as the venerated chief among French mathematicians, sustaining the great traditions of the past and sympathetic with the rising workers of his later days.

A. R. F.

* "Sur quelques applications des fonctions elliptiques"; it appeared in the 'Comptes Rendus,' vol. 85 (1877), vol. 86 (1878), vol. 89 (1879), vol. 90 (1880), vol. 93 (1881), vol. 94 (1882); and the various parts were afterwards gathered into a quarto volume of 146 pages (Paris, Gauthier-Villars, 1885).

HENRI DE LACAZE-DUTHIERS. 1821—1901.

By the death of Henri de Lacaze-Duthiers, Member of the Institute of France, Zoology has lost a worker whose influence on the study of marine Invertebrates it would be hard to overestimate. Not only was Lacaze-Duthiers an able investigator, but he was conspicuous for his success as the head of an important school where many distinguished zoologists have received their training, as the founder and editor of the "Archives de Zoologie Expérimentale et Générale," and by no means least as the originator of the Marine Zoological Laboratories at Roscoff, in Brittany, and Banyuls-sur-Mer, on the Mediterranean coast of France.

The key-note of Lacaze-Duthiers' work is struck in the introduction to the first volume (1872) of his Journal. "Etre expérimentale: "tel est le caractère que doit avoir désormais la Zoologie." By "expérimentale" is understood something widely different from investigations into "Entwickelungsmechanik," or from those which concern the breeding of new races. Thus, in discussing the affinities of *Laura gerardiæ* (1882), he feels the need of further information with regard to the metamorphosis of *Sacculina*, and points out that, by accurately ascertaining the conditions under which this animal lives, it may be possible to keep its young stages alive in order to study their development. "Il faut en un mot faire de la '*zoologie expérimentale.*'" "Experimental zoology" is, in fact, the use of morphological methods of research, combined with the study of bionomics.

Lacaze-Duthiers excelled in the art of making minute dissections. In one of his latest works (1900), he deplores the fact that "on ne dissèque plus." The method of serial section-cutting is said to be responsible for this result, and though indispensable in certain cases, it replaces too often study by actual dissection. The view here indicated dominates the whole of Lacaze-Duthiers' work, which in spite of his practical refusal to avail himself of modern methods, contains many results of great importance.

Where so much is good it is difficult to select the best, but Lacaze-Duthiers is probably most widely known for his researches on the morphology of Mollusca and Cœlenterata. His earlier memoirs were published in the "Annales des Sciences Naturelles," a journal which he forsook for his own "Archives," from the commencement of the latter in 1872. His first work of any importance appears to have been the series of papers on the genital armature of Insects, published in the "Annales," from 1849 to 1853, and immediately followed by a treatise on Galls, which appeared in the botanical

section of the same journal. For some years after 1853, his principal interest was in the Mollusca. In 1854 and 1855 he was engaged in the study of Lamellibranchs; the memoir on *Anomia* demonstrating the fact that this somewhat aberrant form does not differ essentially from other Lamellibranchs, and is in no sense transitional to the Brachiopods; those on the generative organs and the organs of Bojanus in the same group also contributing largely to the advancement of the knowledge of this division of the Mollusca. In 1856 and 1857 appeared one of his best-known works, the classical account of the anatomy and development of *Dentalium*. Some of the figures published in the memoir on *Bonellia* (1858) have re-appeared in almost every zoological text-book, while the papers on *Pleurobranchus* and *Haliotis* (1859) are hardly less well known. During a visit to Minorca, in 1858, he noticed an "ignorant fisherman" marking his clothes with the "purple of the ancients." This event led to the publication of the scholarly "Mémoire sur la Pourpre" (1859), in which, by the citation of classical authorities and in other ways, he established the fact that the purple was probably that which is produced in certain species of *Murex* and *Purpura*, by what is now known as the hypobranchial gland; and showed that the secretion of the gland acquires its final colour by exposure to the sunlight. A summary of this work appeared in vol. x of the "Proceedings" of this Society. Lacaze-Duthiers returned to the same subject in 1896, in introducing to the readers of the "Archives" an archæological memoir on the purple by M. Dedekind.

The French occupation of Algeria was responsible for the appearance, in 1864, of one of Lacaze-Duthiers' most celebrated works, the "Historie Naturelle du Corail." A special administration having been created for the affairs of Algeria, M. le Comte de Chasseloup-Laubat, the head of the administration, bethought himself of the interest which he had taken, in 1834, in the fishery of Red Coral in that locality, and decided that a scientific enquiry should be made on the subject. The work was offered to De Quatrefages, whose occupations did not permit him to undertake the task, and he accordingly wrote, in 1860, to Lacaze-Duthiers, inviting him to study the question. Lacaze-Duthiers accepted the offer, and at once went to Algeria, charged with an official mission to study the natural history of *Corallium*. The work occupied him for two years, and the memoir which was its result, illustrated by beautiful figures drawn by the author, immediately took a leading place in the literature of the Alcyonaria. An admirable account is given of the structure of *Corallium*, including that of its skeleton, of the reproductive phenomena, and of the metamorphosis of the larva, while the practical aspects of the question are treated with the author's

characteristic thoroughness. An interesting history is given of the discovery by Peyssonnel of the animal nature of *Corallium*, and of the incredulity with which Peyssonnel's results were received by Réaumur and Bernard de Jussieu.

The work on the Red Coral was succeeded by the memoirs on *Gerardia* (1864), and other Antipatharia (1865). These papers added not a little to the proper understanding of this group of Zoantharia, and, in particular, they gave much needed information as to the characters of the living polypes of the "Black Corals."

Continuing his researches into the structure and development of Actinozoa, Lacaze-Duthiers published, in 1872, his classical memoir on the development of the Actiniaria. The account there given of the order of the appearance of the mesenteries forms the basis of our modern knowledge of this subject, and is well known to every student of Sea Anemones. This memoir appears in the first volume of the "Archives de Zoologie Experimentale et Générale," of which the first number was ready for distribution in 1870, although the outbreak of the Franco-Prussian War, in that year, delayed its appearance until 1872. Lacaze-Duthiers' activity at this period is strikingly shown by his own contributions to the first volume of the "Archives." Besides the work on Actinians, the volume contains a study by him of the otocysts of Molluscs, another on the structure of aquatic Pulmonate Gasteropods, besides notes on the occurrence of the stalked larva of *Antedon* at Roscoff, and on the remarkable Chætopods, *Chætopterus* and *Myxicola*, observed at the same place. The treatise on the otocysts was summed up in the generalisation that the "auditory" nerves of Mollusca always originate from the supra-œsophageal ganglia, in the neighbourhood of the optic nerves. The supra-œsophageal ganglia are thus the centre which supplies the principal sense-organs; while the pedal ganglia, with which the nerves of the otocysts are often apparently connected, are purely motor in function. There are, perhaps, few anatomical figures of Invertebrates which have more frequently been copied than that of *Cyclostoma elegans*, which is published in this paper. The memoir on aquatic Pulmonates, besides giving an elaborate account of many other structural details, contains a description of a sense organ which has often been referred to as "Lacaze's organ," and was later identified by Spengel with the "olfactory organ" of other Molluscs, a structure now usually known by Lankester's term "osphradium."

In the succeeding volume of the "Archives" (1873), Lacaze-Duthiers reverts to the Actinozoa in a paper dealing with the anatomy and development of *Astroides calycularis*. Here again he had the good fortune to break fresh ground, and his paper was not only the

first to give a satisfactory description of the development of one of the Zoantharian Corals, but the account therein contained of the development of the theca and septa is indispensable to all students of this group.

In 1882, Lacaze-Duthiers published his account of *Laura gerardiæ*, a remarkable type of parasitic Crustacea. This had involved a new visit to Algeria, undertaken with the object of further elucidating the structure of certain organisms which had aroused his interest during the first visit; and among these objects *Laura*, of which a preliminary description had been published in 1866, occupied a foremost place. The difficulties to be overcome were not slight; and among them the principal one was to obtain a supply of the *Gerardia* which forms the host of the parasite. The occurrence of unbroken colonies of this large and fragile Antipatharian in any locality shows that that spot has not been disturbed by the Coral-dredgers; and any fisherman who finds an uninjured colony of *Gerardia* is careful to conceal the fact that he has discovered a bank which may harbour the precious Red Coral.

The investigation of this subject showed that *Laura* belonged to an entirely new group of the Cirripedia, for which the name Ascothoracida was proposed. The structural details described are of great interest, and not least of all in offering a fresh illustration of the tendency shown by the Cirripedia to exchange their normal life as animals fixed to some inanimate body for a condition of parasitism. The adaptations to a parasitic existence shown by *Laura* differ in a striking way from those which have been evolved in other Cirripedes which have independently acquired the same habit of life. Although one or two other genera of Ascothoracida have more recently been discovered (to one of which the name *Petrarca* has fitly been given), Lacaze-Duthiers' account of the type-genus is still by far the most complete that has appeared of any member of that sub-order.

It has only been possible to touch on a few of Lacaze-Duthiers' contributions to Invertebrate morphology. Besides the smaller communications contained in the "Comptes rendus," from 1853 onwards, there are the well-known larger memoirs on *Vermetus* (1860), Brachiopods (1861), Ascidians (1874, 1877), *Aspergillum* (1883), *Testacella* (1887), and others.

His activity showed but little sign of slackening even towards the close of his life. He published voluminous papers on Actinozoa in 1895, 1897, and 1900; while during the last decade there appeared a beautifully illustrated account of the Cynthiidæ of Roscoff, written by him in collaboration with his former pupil, Professor Yves Delage.

In the midst of his own researches, Lacaze-Duthiers found time for establishing and carrying on the marine stations at Roscoff and

Banyuls. The former was founded in 1872 and was later constituted an annexe to the Laboratories of the Sorbonne. The "Laboratoire Arago," at Banyuls-sur-Mer, was established in 1881 with the aid of a public-spirited contribution offered by the Municipal Council of that town. These laboratories have had the double object of bringing students of Zoology into contact with living marine animals during the first years of their study of Biology, and of encouraging original research. For the latter object they have been thrown open to Zoologists from all parts of the world, with a hospitality to which the writer of these lines can testify from two separate visits to Roscoff. It is unnecessary to comment on the results of the enlightened policy which has given these admirable institutions a world-wide reputation.

Lacaze-Duthiers' efforts were not unrecognised in his own and other countries. He was Professor successively, and for about half a century, at the Faculté des Sciences of Lille, and at the École Normale, and at the Museum and Faculté des Sciences of Paris. In 1887 his portrait was subscribed for by many of his pupils and other friends, as a token of the esteem in which his work was held. In 1897 he became a Foreign Member of the Royal Society. In 1900 the Faculté des Sciences of the University of Barcelona presented him with his bust, in recognition of his services in founding the Laboratory at Banyuls, and of the hospitality there shown to naturalists on the other side of the Spanish frontier. With this movement was associated a Committee including the names of many of the most distinguished Zoologists all over the world, and the presentation was made with impressive ceremony at the Sorbonne. The diploma of "Membre protecteur de la Société espagnole d'Histoire naturelle," a distinction previously granted only to four members of ruling houses, was bestowed on him at the same time.

The presentation at the Sorbonne proved to be one of the closing events of his life. Lacaze-Duthiers died at Las Fous in Périgord, on July 21, 1901, in his 80th year.

S. F. H.

CHARLES MELDRUM. 1821—1901.

Charles Meldrum was born at Kirkmichael, Banffshire, in 1821, and was educated at the University of Aberdeen, where he proceeded to the degree of M.A. In 1846 he was appointed to the Education Department of the Bombay Presidency, where he remained only two years. He was transferred to the Mauritius, as Professor of Mathematics at the Royal College.

Meteorological observations had, at that time, been carried on in the island for considerably more than a century, but in a spasmodic way; but in 1851, by the united efforts of Mr. C. J. Bayley, Lieut.-Col. Robe, C.B., Lieut. Fyers, Mr. Meldrum, and others, the Mauritius Meteorological Society was founded on August 1, for the express purpose, *inter alia*, of establishing a permanent magnetical and meteorological observatory in the island, and Mr. Meldrum was appointed one of its secretaries.

The main meteorological work carried on was the examination of the logs of all ships visiting the port, so as to collect information tending to the further development of the Law of Storms.

In the year 1859, meteorological instruments were installed in the old Government Observatory, and, in March, 1862, Mr. Meldrum was appointed Government Observer. Very soon after came on a critical period in the history of the nascent institution. Port Louis, where it was situated, is encircled by hills, and the want of a station in a more suitable locality was seriously felt. This idea had been broached by Dr. Thom even in 1853. In April, 1860, it was recommended that the observatory be sold, and that a new observatory be erected out of the proceeds. This sale was not carried out until the arrival of Sir H. Barkly, as Governor, in 1863. The site fetched £5,200, but several years elapsed before the new building came into existence. It 1866, Mr. Meldrum was sent to England to procure plant for the observatory and the necessary instruments for its outfit. In all these negotiations the late Sir E. Sabine, at that time President of the Society, took a most active part. Mr. Meldrum returned to the colony in 1869, and on Monday, May 30, 1870, the first stone of the new observatory was laid by H.R.H. The Duke of Edinburgh. It was not, however, until the beginning of 1875 that the full outfit of self-recording apparatus for meteorology and terrestrial magnetism came into actual operation.

The observatory was designated as the Royal Alfred Observatory. Its site, at Pample Mousses, seven miles N.N.E. from Port Louis, is not a happy one, as the ground around is marshy and fever-stricken.

Mr. Meldrum's chief work, at first, was the extraction of meteorological observations from the log of every ship touching at Mauritius, and from this source he amassed a store of facts which he knew well how to utilise. Part of this was employed in the preparation of the cyclone tracks for the South Indian Ocean, a work subsequently published by the Meteorological Council.

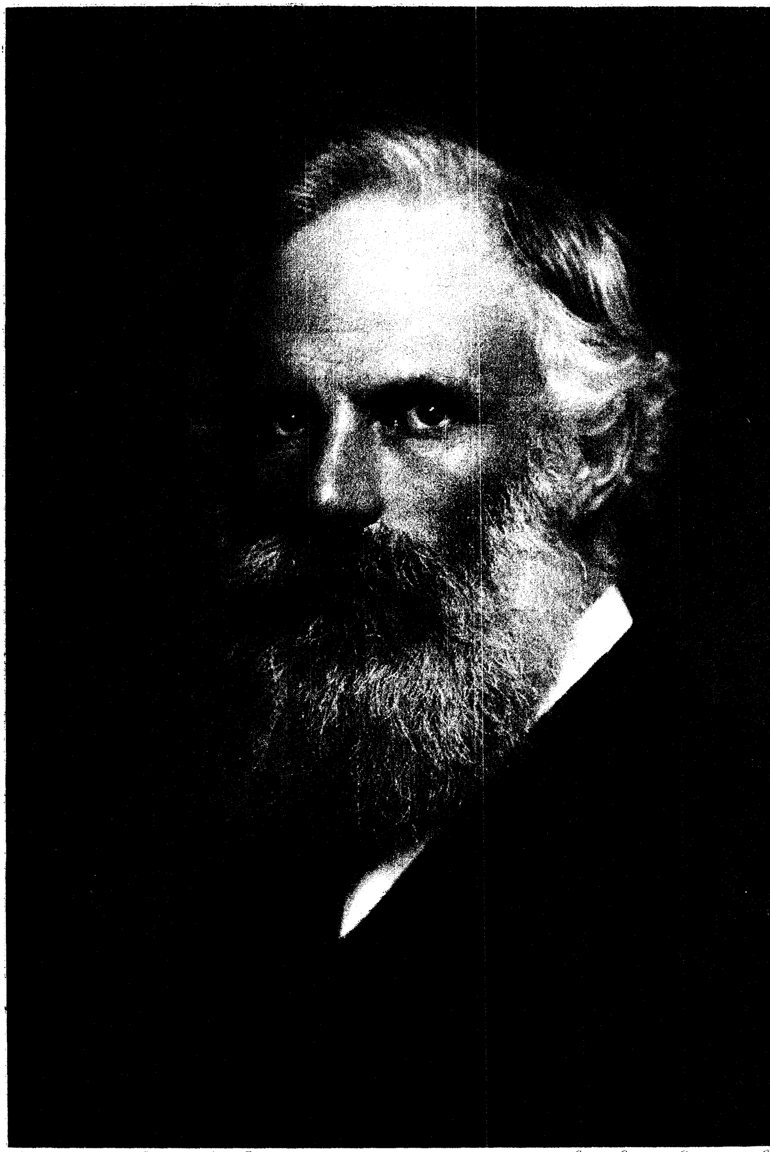
Mr. Meldrum will chiefly be known by the persistent energy with which he studied the connection between the sun-spot period and the recurrence of the cyclones which too frequently devastate the waters round the shores of Mauritius. He early established a system of warnings for the cyclones approaching the island, and these were speedily found to be of value and were implicitly trusted in the port.

Mr. Meldrum received the degree of LL.D. from his own university. He was elected into this Society in 1876, and received the honour of C.M.G. in 1886. He was for ten years a Member of the Government Council of the island. In 1896 he returned to England in very failing health, and after four years of suffering he was at last released in August of this year (1901).

R. H. S.

GEORGE FRANCIS FITZGERALD. 1851—1901.

A thorough attempt to estimate the scientific value of FitzGerald's life and work cannot yet be made: a summary of his published writings can be given, and an indication can be added of the high estimation in which he was held by scientific men in these islands. To the foreigners and to men who have not been brought into immediate contact with him his reputation may seem hardly intelligible; and, indeed, we are often constrained to plead guilty to a sort of family affection existing among British Physicists, and a sympathetic understanding running through our appreciation of them, which tempts us occasionally to be unduly inattentive to some of the first-class work of Physicists outside. It is not a fault on which we pride ourselves: it is one which we lament: it is one which may shortly cure itself, as death removes one after another of those countrymen of the last generation whom we have held in such high honour. The time will doubtless come when with our eyes opened by bereavement, we can estimate in a manner less hampered by intimate insular knowledge the equal achievements of foreigners; but meanwhile we must plead as excuse the extraordinary personal



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Geo. Fra. Fitzgerald

merit and character of some recent Physicists, notably of FitzGerald, in whom those who knew him best could detect least flaw. But foreigners came under the same influence when they were brought into contact with him, witness Ostwald at Leeds, and Lenard at Liverpool; it may be doubted whether there ever was a man of equal scientific power, agility of thought, and selflessness, combined.

George Francis FitzGerald was born on August 3, 1851, and died on February 22, 1901, before he was 50 years of age.

He was the second son of the Rev. William FitzGerald, D.D., afterwards Lord Bishop of Cork, and later of Killaloe: being at the time Rector of St. Anne's, Dublin. His mother was a sister of Dr. G. Johnstone Stoney, F.R.S. He did not go to school, but was educated at home under stimulating circumstances, and to this fact may be attributed some of the retention of his innate originality.

He was not specially remarkable for early ability, as he did not possess any conspicuous faculty for acquiring languages or other learning involving verbal memory; he was good at arithmetic, algebra, and Euclid, of an inventive turn of mind mechanically, and skilful with his fingers in sewing, knitting, and such work; also he developed considerable athletic powers, though he was never specially competent at games.

While still only 16 he went to Trinity College, Dublin, where he soon took a high place; and on obtaining his degree, in 1871, he won the University Studentship, with two First Senior Moderatorships in Mathematics and Experimental Science.

During six years of post-graduate study for the Fellowship, he laid the foundation of his deep and wide knowledge of Physical Science, by study of the classical writings of some of the Masters in Mathematics and Physics, notably Lagrange, Laplace, Hamilton, and MacCullagh. He also made some study of Metaphysics, and was permanently attracted by the philosophy of Bishop Berkeley.

In 1881 he was elected to the Erasmus Smith Professorship of Natural and Experimental Philosophy, vacant by the death of Prof. Leslie; and work gradually began to accumulate upon him. Fortunately he was able to turn his mind readily and persistently to anything that was brought before him, and in the midst of interruption could sit absorbed in either reading or jotting down calculations, sometimes of considerable complexity. But the leisure for long patient analysis was not his, nor did his genius altogether lie in this direction: he was at his best when, under the stimulus of discussion, his mind teemed with brilliant suggestions, some of which he at once proceeded to test by rough quantitative calculation, for which he was an adept in discerning the necessary data. The power of grasping instantly all the bearings of a difficult problem was his to

an extraordinary degree, and it was rare indeed that a thought or a difficulty could be presented to him over which he had not at some period previously brooded. If it were not so, if the ideas were really then presented for the first time, his quickness in seizing them was miraculous. It is easier to suppose that during his long and strenuous course of reading, and in the stimulating mental atmosphere of Trinity College, in conversation also with his uncle Dr. Johnstone Stoney and others, nearly all the problems in physics likely to occur to contemporaries had in some form or other come within his ken: and hence hardly anything that could be suggested seemed altogether new and strange to him. Nor did his knowledge seem to have sunk into any kind of oblivion; there it was always accessible, and with an added commentary of his own quite ready, to the surprise and delight of those who conversed with him.

So, for instance, occurred his perception of the influence of light-pressure in Astronomy; also of the emission by the Sun of electrified particles which streaming past the earth might give rise to magnetic storms and auroræ, before our knowledge of electrons made this idea easy or quantitatively feasible. So also occurred that brilliant suggestion of the change of shape or distortion due to motion through ether, now known as the FitzGerald-Lorentz hypothesis, which flashed on him in the writer's study at Liverpool as he was discussing the meaning of the Michelson-Morley experiment. Of this nature also was his suggestion to utilise the oscillatory discharge of a Leyden jar as a means of exciting ether waves: an idea which roughly had occurred to others before (the writer finds it in one of his own note-books of date 1879—80), but with FitzGerald it became quickly definite, leading him to investigate not merely the easy problem of the wave-length to be expected, but the much more difficult question of the amount of power that would be radiated by an alternating current in any given case.

Directly Hertz's experiments were published, FitzGerald discerned their whole significance, and in his brilliant Presidential address to Section A of the British Association, at Bath, called the world's attention to them in an unmistakable manner. Had it not been for the English recognition they received it is improbable that the work of Hertz would have been hailed with the immediate chorus of universal approbation which it commanded, for the work of his own countrymen had mainly laid on other lines; and even to Hertz himself the theory of Clerk Maxwell only gradually, and subsequently to his verifying experiments, became quite clear and familiar. Undoubtedly FitzGerald recognised more vividly than Hertz himself at that time the full import of his experiments,—the German title of which was far from representing the plain significance of the title

applied by Lord Kelvin to the later English translation, viz., "Electric Waves." This is no disparagement to Hertz: rather it strengthens our admiration of him to perceive how quickly and perfectly he could emancipate himself from national traditions, and constitute himself an apostle, and one of the most powerful exponents, of the Maxwellian Theory of Light.

But to FitzGerald all this was fundamental and familiar—he had got beyond the analysis, and revelled in full-bodied conception and pictorial imagery and mechanical models of what was going on: and these clear perceptions of his, with a realisation of much of the outcome that might be expected, were really of more value and contributed more to the progress of science than did his own laborious analytical investigation of the Electro-magnetic Theory of the Reflection of Light from Insulators, from crystalline bodies, and from magnetised media, which constitutes his chief systematic memoir: powerful and impressive as the complete mathematical analysis of so difficult a subject necessarily was.

Another aspect of the man was his extraordinary and sympathetic critical power. He did not seem to mind reading other people's papers and proofs: entering into their point of view seemed to him to present no difficulty, nor did the immediate correction of blunders into which they might have fallen seem to present any difficulty, or suggest any claim to superiority.

As an ordinary man could correct a schoolboy's sum, or an exercise in simple mechanics or geometry, so he could tackle a difficult Royal Society paper, or a Treatise, say on Thermodynamics or on Physical Chemistry, and point out both the merits and flaws in it at once. Never was anyone so clear on the subject of the pitfalls which once awaited the unwary chemist or applier of the second law of Thermodynamics to physical and chemical problems. The result being correct, or at least acceptable, it is so easy to bolster it up by a false application of quasi-mathematic or thermodynamic reasoning; but all such fallacies were instantly detected by FitzGerald, and the essential requirements of both reversible and cyclical processes, as the basis of systematic theory, insisted on.

Suggestions for experiment frequently occurred to him, but were seldom carried out with his own apparatus; rather he preferred to hand on both the labour and the honour of an experimental research to some assistant or student, to whose reputation a successful result would make all the difference; and many results obtained by others probably owe their initiation to him.

By reason of these peculiarities of disposition his published memoirs may not impress foreigners, or those who did not know him, with a proper idea of his real magnitude; but it is probable

that they will nevertheless produce a very considerable impression. For so many of his contributions to science were made to the Royal Dublin Society (of which he acted as Secretary from 1881 to 1889) or orally to the British Association, neither of which agencies are specially well adapted for informing the world generally, that to many the memoirs which will shortly be published, under the careful editorship of Dr. Larmor, will be new, and will come as a revelation of solid and industrious work.

Nevertheless, once more it must be said that his wide knowledge, and brilliant speculations based upon that knowledge, were what impressed his friends the most. Sometimes they seemed almost too fanciful, too far-reaching ahead of solid fact, too intangible and fantastic to be attractive; that is the case to some extent, for instance, with parts of the Helmholtz Lecture, where the beauty and the possibilities of the vortex hypothesis of the constitution of matter and of the structure of the ether entice him into regions where substantial mathemathical progress is hardly yet possible. Into this region, however, the human race must advance, if it is to proceed with the unification of matter and the more fundamental understanding of the material universe; and our descendants—the possessors of an elaborated theory—will be able to judge better than we can how far these speculations of FitzGerald were fantastic imagination, and how far they were the outcome of a real and semi-inspired insight into the inmost processes of Nature.

But in spite of his ready absorption in these physical topics and his almost unique power of quickly grasping and fruitfully dealing with them, he was imbued with a sense of the far greater importance of humanity itself than of any of these material things. In fact it was this constant feeling of the value of human relationships, and the supreme influence of good feeling and affection, that led him to regard all questions of priority or of scientific credit with not so much disdain as absence of interest. It is easy to say that provided a discovery is made it matters little who makes it, but it is not so easy constantly and consistently to feel and act in that spirit; but so far as it can be done FitzGerald did it, and did it apparently almost without an effort. The things he really valued were the things belonging to the human spirit—the development of the individual and the development of the race. Any thing which hindered this met with his strenuous opposition: self-satisfied unprogressiveness in educational matters excited his wrathful and outspoken indignation: and on these subjects alone did he occasionally make enemies. Other things might be of intense interest but were not of supreme value and to sacrifice any personal relationship to them was worse than useless.

With all his critical power he seldom expressed himself severely on the scientific mistakes of others. I have once or twice heard him speak of some man as small or narrow, and I have heard him wax indignant over some charlatan who pretended to be what he was not; but these were exceptional instances, and as a rule this mood had to be worked up by others: it did not arrive spontaneously. Generally he saw the best in people; and, like Lord Kelvin, was able to disentangle ideas of value from the crude efforts at presentation of a beginner or of an ordinary muddle-headed man.

Gradually as he grew older the sense of public duty grew upon him, and he was prepared to spend his time in public service to an extraordinary, and as some thought a wasteful, extent. In 1888 he was appointed a member of the Board of Irish National Education, and devoted a large amount of time to work not free from controversy; and shortly before his death he was appointed, with five others, to the Intermediate Education Board. Had he lived (he has written to his uncle, Dr. Johnstone Stoney) he would have sought to devote himself to the organisation of National Education rather than to the uninterrupted pursuit of his science,—saying with complete sincerity that whether the human race got to know about the ether now or fifty years hence was a small matter, but whether the present state of appalling scientific ignorance was to continue for another generation was a vital matter affecting the future of his own country in a positive and definite way.

The portentous backwardness of this country (not Ireland alone) in education does indeed call for sacrifice on the part of those who clearly realise it; and into this work FitzGerald would undoubtedly have thrown himself. Until a general level of scientific knowledge has been attained by a nation, it cannot expect its great men to forge on ahead and continue their advanced studies with satisfaction to themselves. Already they have been feeling too isolated and aloof from humanity, and a feeling of the futility of it all, based upon the entire uncomprehension of the multitude—an uncomprehension shared under our present system of education by the great bulk of so-called educated men,—is apt to make itself unpleasantly prominent every now and then, and to lead gradually to the belief, at which FitzGerald arrived, that greater service could be done by working towards the raising of the general level than by a pioneering quest, solitary or with only a few like-minded spirits, into lands too far removed from human traffic to be capable of utilisation and absorption for generations to come; perhaps, therefore, to be forgotten and ignored altogether, until re-discovered independently hereafter, at a time when the general level of intelligence in scientific directions shall be higher than it is now, and can enable it to be appreciated and retained.

The authorities of Trinity College, Dublin, are bringing out a memorial edition of FitzGerald's writings, under the supervision and editorship of his friend and equal, Dr. Joseph Larmor; who has likewise written a powerful general summary and estimate of his scientific work, so far as it can yet be estimated, for the *Physical Review* for May, 1901; which will be reprinted with notes and additions in the volume of FitzGerald's collected works. To this memoir the student of advanced Mathematical and Physical science is referred. It is thought better to restrict this present notice to matters of more general interest, but it may be permissible to conclude with a few quotations from the pen of some of his contemporaries, Heaviside, Ramsay, and others, which appeared at greater length in the pages of *Nature* for March 7, 1901:—

"At the last meeting of the British Association (at Bradford, 1900) the proceedings of the Physical Section were interesting and successful from one cause beyond all others—the assiduity with which he devoted himself to attendance, and the unceasing flow of valuable suggestion and appreciative criticism which he contributed. His stores of knowledge were ripening and maturing in fibre year by year; his memory was unfailing, and each new fact or phenomenon seemed to find its place at once in the setting to which it belonged. Whatever views were presented to him, however much they jarred with his own ideas, were certain to receive patient and careful consideration. There was nobody who did more to encourage younger men and to bring out what was best in them; the time which he was accustomed to devote without stint to the elucidation and improvement of the work of others sadly diminished the opportunities for work more especially his own. His advice and judgment were valued over the whole range of Physical science, not less in foreign lands than at home, notwithstanding that he published so little. When a Physicist or physical Chemist came to a puzzle or paradox, or was in doubt between various plans of procedure, it seems to have come to be almost the natural course to write to FitzGerald. A letter of inquiry or criticism always elicited a prompt reply, entirely devoid of pretension to magisterial authority, but certain to bring out new aspects of the subject and exhibit its connection with other problems. He was constantly acting as referee of scientific papers for the Royal Society and other bodies, and was accustomed to interest himself in them as if they were his own work." J. L.

"He had, undoubtedly, the quickest and most original brain of anybody. That was a great distinction; but it was, I think, a misfortune as regards his scientific fame. He saw too many openings. His brain was too fertile and inventive. If be had been less

quick and versatile and more plodding he would have been better appreciated, save by a few." O. H.

"FitzGerald had no trace of intellectual pride, he never put himself forward, and had no desire for fame; he was content to do his duty. And he took this to be the task of helping others to do theirs. Although he held strong views on many points, and could defend them with vehemence, his argument was never a personal one; and it was obvious that he was actuated solely by a love of truth, and that his only object was to defend what he thought to be right. Moreover, what FitzGerald thought to be right was pretty sure to turn out right in the long run." W. R.

From an obituary notice in the *Electrician* for March 1, 1901, the following:—

"He possessed extraordinary versatility, and could turn his mind almost instantly to anything, but the instant it was so turned it went deep into the subject, to the exclusion of other things for the moment; and in the deepest subjects he was more at home than in the trivial and superficial. But he was never a recluse; had he been more of a recluse perhaps his great power of intimate brooding and absorption, combined with his wide mathematical knowledge and preparedness, might have led him to some epoch-making discovery. But if so he did not give himself the chance, his place was with the captains and the shouting, and the intervals of leisure for real continuous work were few and far between." O. J. L.

A communication from Lord Kelvin, which appears as the conclusion of Dr. Larmor's memoir above referred to, shall not have an extract removed from the context.

But on the personal side, the following extract from an appreciation in the *Athenæum*, attributed with some probability to Professor Mahaffy, may be quoted:—

"His appearance was not unworthy of his fame. More striking he was than handsome; but his ample grey locks and beard, his furrowed brow, his penetrating eyes, reminded one of the bust of some Greek philosopher, which we cannot look upon without that instinctive feeling of respect which intellect and character command among civilised men."

And the following by Larmor:—

"His scientific place will be henceforth alongside Rowan Hamilton and MacCullagh and Humphrey Lloyd, and the other famous men who have secured for the Dublin school so prominent a position in the edifice of modern physical science. In the higher domain of heart and conduct the recollection of his qualities will be an abiding treasure to all who knew him."

FitzGerald was elected a Fellow of the Royal Society in 1883, and

in 1899 was awarded a Royal Medal. He married, in 1885, Harriette M., second daughter of the late Rev. J. H. Jellett, D.D., Provost of Trinity College, Dublin, to whom the next previous award to an Irish man of Science of a Royal Medal had been made. One who had unrivalled opportunities of appreciating these two men remarks on "the great likeness in the two characters: the great simplicity, the directness of purpose, the utter absence of preaching but the living of the life that is best; their great tenderness and love of children."

The "idealistic" turn of his mind in dealing with ultimate questions came out constantly in his conversation on such topics, and may be illustrated by a quotation from the end of his Helmholtz Lecture. After noting that all forms of external stimulus, into whatever terms we translate them—sound, colour, and the rest, nay, even space, time, and substance too, perhaps—resolve themselves into motion, he goes on to ask: "And what is the inner aspect of motion? In the only place where we can hope to answer this question, in our brains, thought [turns out to be] the internal aspect of motion. Is it not reasonable to hold, with the great and good Bishop Berkeley, that thought underlies all motion" . . . . . "For the highest life we require the highest ideal of the Universe to work in. Can any higher exist than that, as language is a motion expressing to others our thoughts, so Nature is a language expressing thoughts, if we learn but to read them."

He insisted on the ether being not a simple fluid, with the atoms as vortex rings, but a medium itself full of motion,—a vortex "sponge" or assemblage of vortex filaments; and by help of such a medium he hoped ultimately to be able to explain not only light and electricity but the structure and properties of matter, all its physical and chemical agencies, and the material universe generally. But always he was well aware that such would be no ultimate explanation, that what we are really and primarily aware of is mind and mental processes, that thought and feeling are primary facts of consciousness, while all else is an inference and is probably essentially unlike what it appears to our senses: so that all this cosmic whirl and material activity, and probably life itself, would resolve itself, when properly comprehended, into the activity of an all-pervading and beneficent Mind.

O. J. L.

HENRY TRIMEN. 1843—1896.

To write the memorial of a personal friend whose scientific career has run parallel with one's own is, at the best, a sad task. If I have not hitherto performed it for Henry Trimen it is because, as often as I have attempted it, the accomplishment has seemed too painful.

Henry Trimen was born on October 26, 1843, at Paddington, Middlesex. He was the youngest of four brothers, of whom the third was Roland, one of our Fellows, and a distinguished etomologist. The father, Richard, traced his ancestry to a stock which, under similar names, exists both in Cornwall and Brittany. He himself, a man of easy circumstances, was—without any scientific pretension—a great lover of Nature, and an excellent observer; he possessed, too, a keen artistic perception, and some ability in execution.

The two younger brothers were closely associated in their early bringing up. They derived from their father, both by inheritance and example, an early delight in natural objects. He continually encouraged them in their attempts to form collections of shells, insects, plants, fossils, etc., often accompanying them in country excursions, and pointing out interesting animals and plants. The elder brother remembers how, when it became necessary to restrict in some definite direction accumulations which were becoming unmanageable, it was solemnly decided that Henry was to occupy himself with plants, and Roland with insects. Henry, however, never so completely specialised as to lose all taste for other branches of natural history. These facts, if apparently trivial, are worth recording, because the process by which a naturalist is now evolved has, during the last half century, undergone a complete change. It may indeed be doubted whether the class itself is not on the verge of extinction.

Trimen entered King's College School in 1855. There I made his acquaintance on the strength of a "collecting tin," familiar to botanists, which I saw him one day carrying. It may be doubted whether, now-a-days, in a London day-school, two boys would be found to strike up a life-long friendship on a common taste for field botany.

Companionship once established, we spent most of our half-holidays in excursions round London. With the ambition of schoolboys, we soon projected a Flora of Middlesex. We kept careful notes of our excursions, and spared no pains in the critical determination of the plants we collected. The material gradually accumulated, and at last we determined to undertake a detailed botanical survey of the county. Latterly we had to divide the work, exploring different districts separately. On one occasion, Trimen, while examining a wood in the northern part of the county, encountered a fellow collector, who

turned out to be John Stuart Mill, known, perhaps, to few as an ardent field botanist. On another occasion, in 1866, Trimen had the good fortune to discover, at Staines, *Wolffia arrhiza*, which was new to the British Flora, and which is remarkable as the smallest known, as it is, perhaps, the smallest possible, of flowering plants. As the work proceeded, we derived much assistance and encouragement from the Rev. W. W. Newbould and the Hon. J. Leicester Warren (afterwards Lord de Tabley), both of whom are dead.

We soon found that the task we had undertaken, if an interesting, was by no means an easy one. The continuous growth of London gradually obliterates the natural vegetation. Areas long since covered with houses had been the hunting ground of some of the fathers of English botany, such as Turner, L'Obel, and Gerarde. We were therefore obliged to engage in an exhaustive study of all the records of Middlesex plants to be found in botanical literature, from the earliest times, and to spend a considerable amount of labour in reducing their names to modern equivalents.

The result was sufficiently striking and of some scientific importance. Although only 141 square miles in area, and, at first sight, far from promising any but moderate results, we obtained, either from trustworthy records, most of which we were successful in confirming, or from our own observations, definite evidence of the occurrence in the county of 826 species out of a total in the British Isles of 1425, and some material additions have since been made to our enumeration.

The Flora was published under our joint names in 1869. Critics have amiably described it as "an epoch-making book in the history of British botany," and "a model for subsequent compilers of local floras." I have the less hesitation in acquiescing in these favourable judgments, as the book owes its merits almost entirely to Trimen's labours. The task fell upon him of writing out the manuscript for the press, and condensing the large accumulations of notes and observations into a lucid and critical summary, and this he accomplished with the fidelity and judgment which always characterised his work. He added, what was entirely his own, a careful study of the life and work of the early London botanists; and this is a valuable contribution to an obscure branch of scientific history.

Trimen entered the Medical School of King's College early in 1860. After spending 1864 in Edinburgh, where he followed the clinical instruction of Professor Bennett, he took the degree of M.B. with honours at the University of London. He acted for a time as District Officer of Health in the Strand District during a cholera epidemic, and also filled the post for some years of Curator of the Medical Museum at King's College, and that of Lecturer on Botany at St. Mary's

Hospital Medical School from 1867 to 1872. He never practised his profession, but in 1869 entered the Botanical Department of the British Museum as an assistant.

From 1870 to 1879 Trimen edited the "Journal of Botany," which had become the repertory for the critical study of the British Flora. He was engaged from 1875 to 1879, in collaboration with his old teacher, Professor Bentley, in the publication of the four volumes of "Medicinal Plants," which is now regarded generally as the standard authority on Pharmacology in this country. It contains singularly few errors, or rather points in which subsequent research has corrected its statements. It exhibits, in a striking degree, the qualities of thoroughness and caution which Trimen eminently possessed.

Trimen was at bottom a naturalist in whom the love of living things was not easily extinguished. About 1879 he began to feel the restraints of museum work irksome. He enquired of me if some congenial colonial scientific post could be found for him. It so happened that just at this juncture the Directorship of the Royal Botanic Garden, Peradeniya, Ceylon, had become vacant by the retirement of the distinguished botanist Dr. Thwaites. The Government felt themselves fortunate in having so capable a man as Trimen to take his place, and though the trustees of the British Museum showed their appreciation of his services by endeavouring to retain them on more favourable terms, Trimen elected to proceed to Ceylon.

The task he undertook proved no easy one, but he fulfilled it for the next sixteen years with signal success. He had acquired some experience of official work at the British Museum, but the larger scope of administrative control, and the somewhat exacting duty of acting as scientific adviser to a planting community, was new to him. The colony had gone through a disastrous crisis, owing to the destruction of its principal staple, coffee, by "leaf disease." The period of transition to new industries was exceptionally trying. It fell to Trimen to assist the planter by answering enquiries addressed to him on every conceivable subject. For this his accurate knowledge and imperturbable good humour made him an almost ideal instrument. His services in this respect were not unappreciated. The *Ceylon Observer* did full justice to him on his death. It wrote: "Never before in the history of the island has more attention been given in our Botanic Gardens to every question bearing on the economic, as well as scientific side of planting, and tropical agriculture generally, than during the last sixteen years." It had never, however, been Trimen's intention, in accepting a colonial post, to subside into the mere official. He had always had the ambition to accomplish some considerable work for science, and in Ceylon he found a task worthy of his ability ready to his hand. A comprehensive work, or Flora, descriptive of the plants

indigenous to Ceylon, had long been demanded. Trimen's predecessor, Thwaites, had prepared the way by accumulating ample collections, and by the publication of an enumeration without descriptions. Ceylon plants had also been included, as far as they were known, in Sir Joseph Hooker's 'Flora of British India.' The vegetation of Ceylon presents, however, a problem in geographical distribution of peculiar interest. Although Indian in type, it yet has striking Malayan affinities, though of a peculiar endemic character. It therefore amply merited an independent study. To this task Trimen soon devoted himself, and steadily worked at it till his death. He had first to carry out a thorough reorganisation of his department, and to remodel the extensive tropical garden, which the failing health of his predecessor had allowed to fall somewhat into disorder. The result excited the admiration of our Foreign Member, Dr. Treub, the Director of the Buitenzorg Botanic Garden. Trimen's hospitality attracted many scientific friends to Peradeniya, and Haeckel wrote: "The seven days I spent in his delightful bungalow were, indeed, to me, seven days of creation."

The first volume of his Handbook appeared in 1893, the second in 1894, and the third, the last he was able to accomplish, in 1895. For some time he had been troubled with increasing deafness. It unhappily continued till he was absolutely deprived of the sense of hearing. This was followed by a loss of power in his lower limbs. He came to England in 1895 for advice. His general health was, however, little affected, and though the nature of his malady completely baffled his physicians, they were not without hope of his recovery. His cheerfulness of mind remained as unabated as his anxiety to complete his Handbook.

The state of his health so obviously unfitted him for his official duties that the Ceylon Government was compelled to retire him on a pension on July 1, 1896. The unanimous vote of the Legislative Council, however, gave him the exceptional privilege of a special allowance, in addition to his pension, for six months "in order to complete the scientific work upon which he is now engaged."

He returned to Ceylon for the purpose, but though he became rapidly worse, and could not move without assistance, he still worked without intermission at the completion of his task. For the last few months of his life he was confined almost entirely to his room. On October 14 he became seriously ill. The following day he rallied a little, and actually attempted to resume work on the Flora, making a few scarcely-decipherable notes. The following day he sank into a state of coma, and passed away painlessly. He was buried not far from the resting place of his predecessor, Dr. Thwaites.

At the request of the Ceylon Government, Sir Joseph Hooker generously undertook to complete the Handbook. This required two

W. Marcet.

more volumes, which appeared respectively in 1898 and 1900, in addition to a quarto volume of plates of the more interesting species, which had been prepared under Trimen's direction. From the papers placed in his hands, Sir Joseph was able to print the important order *Euphorbiaceæ* upon which Trimen had laboured almost to the day of his death, and pretty much as he left it. The rest of the work was contributed by Sir Joseph himself.

The Royal Society Catalogue, down to 1883, enumerates 50 of Trimen's separate papers. He was elected F.R.S. in 1888.

In manner Trimen was somewhat retiring, if not a little shy, perhaps, with an old-fashioned gravity. Though he devoted his life to science, the world, in its wider aspects, was full of interest to him, and he was an admirable correspondent. Of a tolerant and happy disposition, I do not suppose he ever made an enemy. His death was sincerely regretted by the European community in Ceylon, and no less mourned by the natives who worked under him. He died unmarried.

His scientific work belonged to the older rather than to the new school, but he had a strict sense of form and a disciplined literary method. If not brilliant, it is always painstaking, trustworthy and judicious. He was essentially a man of facts, and for theorising he had little taste. Of such men science has ample need.

W. T. T. D.

WILLIAM MARCET. 1828—1900.

William Marcet was born at Geneva on May 13, 1828. He came of a family distinguished in medicine and science. His grandfather, Alexander Marcet (1770—1822), belonged to an old Genevese family, but having been compelled by political circumstances to leave Switzerland, went to Edinburgh, where he took his degree of Doctor of Medicine, and having become a naturalized English citizen, settled in London, and was eventually physician to Guy's Hospital. He published several papers of importance on chemical and physical questions in relation to medicine, and became a Fellow of this Society. After the re-settlement of Europe he returned to Geneva, where he resided until his death. He was married in England to Jane Haldimand (1769—1858), who also belonged to a family of Swiss origin, and who was a woman of more than ordinary ability. She was the author of a number of treatises on education, one of which, "Mary's Grammar," is still in request; while another, "Conversations on Chemistry," went through no less than sixteen editions. Their son, Francis Marcet (1803—1883) was educated at Westminster School, but

went to Geneva at the age of eighteen, and resided there for the greater part of his life. He eventually became Professor of Physics in the Academy of Sciences of Geneva, and Councillor of State, but in 1870 he again took up residence in London. He published many papers, chiefly of chemico-physical and meteorological character, and was also a Fellow of this Society. He served for several years on the Council of University College, London, an institution in which his son, the subject of this memoir, also took a keen interest, and in which in the later years of his life he carried out most of his researches.

With such an ancestry and home surroundings, it is not surprising to find that the bent of William Marcet's mind was in the direction of the elucidation of problems of a chemico-medical and physico-medical nature; thus we find him at different times of his life investigating such chemical problems as the composition of foods and their changes in digestion, the measurement of the amount of heat produced by the human body under varying conditions of rest and activity, and making observations on climatology, the value of which was testified by the election of their author to the distinguished position of President of the Royal Meteorological Society.

William Marcet's boyhood was spent at Geneva, where he was a pupil of M. Toepffer, who appears to have been attracted by the vivacity and originality of his young pupil, whom he has put into his "*Voyages en Zigzag*," under the appellation of Sorbière. After studying for some years in the Academy of Sciences of Geneva, Marcet went to Edinburgh at the age of eighteen to study medicine. He took his degree there in 1850, and shortly after proceeded to Paris, further to work at chemistry under Verdeil, with whom he undertook a series of investigations upon the composition of the blood in man and mammals, and upon the chemical principles of the food and their changes in digestion, the joint articles being communicated to the Société de Biologie. Returning to London in 1853—where he intended to settle down to the practice of medicine, and where he was before long appointed Assistant-Physician to the Westminster Hospital—he continued to pursue these researches upon food and digestion, and in 1856 published a work of considerable importance "On the Composition of Food and how it is Adulterated; with practical directions for its Analysis." In the following year, at the comparatively early age of 29, he was elected a Fellow of this Society, to which, as we have seen, both his father and grandfather also belonged. Soon after this he was appointed Lecturer on Chemistry and Texicology at the Westminster Hospital Medical School. In 1863 he resigned his appointments at the Westminster Hospital, but a few years later, in 1867, was made Assistant Physician to the Brompton Hospital for Consumption, being at this time especially interested in the study of

tubercle. In this year, struck with the importance of the observations of Villemin on the inoculation of tuberculosis, Marcet repeated his experiments, and obtained conclusive results from the inoculation of the products of expectoration of consumptive patients, showing that these results could be employed for purposes of diagnosing tubercle. He more especially interested himself with the laryngeal form of phthisis, and for its appropriate investigation familiarised himself with the use of the laryngoscope, then but recently introduced. He published a small volume on the subject in 1869.

Two other matters to which Marcet devoted his attention during these busy early years of London life were the influence of alcohol upon the animal organism, and the pathological chemistry of the cattle plague, the last-named work appearing in the Third Report of the commissioners appointed to inquire into the "Origin and Nature of Cattle Plague," published in 1866. The results of his researches on alcoholic intoxication were published in 1860, after having been brought before the British Association at the Aberdeen meeting in the preceding year. He also took an active part in the proceedings on a Committee appointed by the Royal Medical and Chirurgical Society to investigate the physiological action of anæsthetics, and the safest mode of administering them.

The interest which Marcet took in the subject of phthisis, combined, doubtless, with a desire to obtain greater leisure during the summer months for the prosecution of researches and for travelling, of which he was always fond, led him to give up his London practice and to establish himself during the winter months in practice on the Riviera. Here he passed nine winters—three at Nice and six at Cannes. From that time he occupied himself almost exclusively with researches having for their object the investigation of phenomena connected with respiration and with the influence of climate and altitude upon it. Marcet was a keen and active mountaineer, and a member of both our own and of the Swiss Alpine Clubs, but he loved to combine scientific observations with the pleasure of climbing, and he would often be accompanied in his ascents by apparatus for the collection of the gases of respiration, the guide whom he took with him serving also as a scientific assistant. In this way he investigated the effects upon the respiratory exchange of altitudes in Switzerland as considerable as the Breithorn (13,685 ft.), the Col Théo dule (10,899ft.), and the Col du Géant (11,030 ft.). Suspecting that the extreme cold experienced at these heights in Switzerland might materially modify the results of altitude, Marcet determined to repeat the observations upon the Peak of Teneriffe, and here in 1878, at heights of from 8,000 to nearly 13,000 feet, he camped out for no less than three weeks, in the company of a guide from Chamounix, making numerous meteorological

observations and analyses of air, under circumstances of extreme difficulty and personal discomfort. His experiences are recounted in his book on "The Principal Southern and Swiss Health Resorts," which was published in 1883, and which contains much valuable information concerning the climatology of the principal places in question. During the last twenty years of his life Marcet gave up practice altogether and devoted his energies during the winter and spring entirely to scientific research, spending the summer and autumn partly in travelling, but mainly residing at his family property, Malagny, near Versoix, on the Lake of Geneva. Both here and at Yvoire, on the Savoy side of the lake, where he resided when in Switzerland, before his father's death, he spent his leisure time yachting and mountaineering. For his winter work, he set up a laboratory in London, at first in his own house, but from 1883 onwards in one of the rooms belonging to the Physiological Department of University College, which was placed at his disposal. Here, with the aid of skilled assistants, he carried on his researches upon the gases of respiration, for which his ingenuity devised a number of new and beautifully-constructed pieces of apparatus, amongst which may be specially mentioned an approved form of spirometer, with a bell accurately balanced at every plane of immersion, and a new form of eudiometer for determining the percentage of oxygen in expired air. Here also he caused to be constructed a large copper chamber enclosed within a jacket of non-conducting material, which he employed as an ice-calorimeter for the human subject, the air inside the chamber being both kept in motion and of a constant temperature by being driven by electric fans over the ice, the melting of which was to serve as a measure of the amount of heat produced during the stay of the subject of experiment within the chamber. This apparatus, which appears to represent the first attempt at human calorimetry by the aid of the ice-method, was ultimately presented by Marcet to Professor Schäfer, and is now set up in the Physiological Laboratory of the University of Edinburgh. The results of Marcet's later observations, both upon the respiratory exchanges and upon the conditions of heat-formation in the human body, were for the most part communicated to the Royal Society and published in the "Proceedings" or "Transactions," usually in the joint names of himself and his assistant—for no one could be more punctilious than Marcet in acknowledging the work of others, even if immediately inspired and directed by himself. Many of his results were collected and published with much additional matter in his "Contribution to the History of Respiration of Man," which appeared in 1897, and was an extension of the Croonian Lectures which he delivered before the Royal College of Physicians in 1895.

The methods which Marcet employed, and the principal facts which they had yielded, were for the most part demonstrated at the meetings of the Physiological Society, of which he was one of the first and always remained one of the most active members. His genial presence will long be missed by his fellow-members.

Marcet was in all things enthusiastic and optimistic; he threw himself into everything which he undertook with unexampled energy, whether it were the pursuit of science, the practice of medicine, yacht-racing, or climbing. His conversation and manners were animated, and, while delighting to discuss scientific problems, he was always careful to avoid saying or writing anything which could wound an opponent. His friends were all who knew him: he made no enemies. Although his general health was good, he was for a long time subject to severe attacks of asthma, which would often be followed by prolonged periods of relative ill-health, but his optimistic disposition soon enabled him to recover his spirits and to throw himself just as enthusiastically as ever into work or play. Towards the end of his life, however, more serious symptoms affecting the heart and kidneys became apparent, so that he was compelled to relinquish all work, and to voyage for the sake of health. It was on such a journey up the Nile that he was seized with the attack from which, on March 4, 1900, at Luxor, in Upper Egypt, he died in the 72nd year of his age.

E. A. S.

Sir HENRY WENTWORTH ACLAND, Bart. 1815—1900.

Sir Henry Wentworth Acland, Bart., was born August 15, 1815, at Killerton, in Devonshire. He died at Oxford, October 16, 1900. He was educated at Harrow, and Christ Church, Oxford. He graduated in Arts (M.A.) in 1840, and in Medicine (D.M.) in 1848. He was appointed Reader in Anatomy at Christ Church in 1845, and became a Fellow of the Royal Society in 1847. In 1851 he was appointed Radcliffe Librarian, and in 1858 Regius Professor of Medicine. In 1874 he was elected President of the General Medical Council.

Acland's scientific career may be said to have begun in 1843, when, having attended the lectures of Professor Owen during the time that he was pursuing his ordinary medical studies at St. George's Hospital, and having thereby acquired an interest in Comparative Anatomy, he repaired to Edinburgh in order to profit by the greater advantages which the northern University then afforded. As a student of anatomy he came under the inspiring influence of John Goodsir, who

was then Demonstrator, and Curator of the Museum, but not yet Professor. Acland appears to have worked in the Edinburgh Museum under Goodsir's direction for two years with great industry, and no doubt acquired a very thorough knowledge both of human and comparative anatomy.

In 1845, when a vacancy occurred in Dr. Lee's Readership in Anatomy at Christ Church, Oxford, he became a candidate for the post and was elected. He thereupon prepared to convey his anatomical preparations to Oxford, and with this view returned from Edinburgh by sea, bringing with him not only his collection, but also his invaluable assistant, Mr. Charles Robertson, whose life from that day to the present time has been with perfect fidelity given to the service of the University.

Acland's arrival in Oxford from Edinburgh with his skeletons and dissections was an incident deserving commemoration, for it marked the introduction into the studies of the University of a new element—the study of living nature, or as we now call it, of biology. Acland's predecessor, Dr. Kidd, had complied with the conditions under which he held the office, by giving instruction in human anatomy with the aid of models and a certain number of permanent preparations; among which a skeleton, which hung from the ceiling of the dingy room which was appropriated to the Reader, is remembered as most conspicuous. Acland, on his appointment, appears to have at once resolved that he would teach anatomy as he had learned it from Goodsir. Although the Founder of the Christ Church Readership (Dr. Lee) had strictly defined the subject to be taught, directing that the holder of the office should confine himself to "explaining and regularly demonstrating . . . all parts of the human body with their uses," he considered himself to be justified in giving a much wider range to his teaching. He, however, followed Dr. Lee's directions so far as to divide his course of lectures and practical instruction into two parts; in one he described the form and structure of the parts of man and animals (Anatomy), and in the other their uses (Physiology). As the whole course was completed in thirty lectures, he could not do more (as he stated to the University Commissioners of 1851) than give his hearers "a sketch of the general nature of the objects of anatomical and physiological knowledge"—his aim being to secure for natural science a place in liberal education, not to train either anatomists or physiologists.

The change that was thus made in the subject of the Readership (which be it remembered constituted the only means of instruction then available in the University for students of biology) had several consequences, each of which had an important relation to future progress. One of these was that for nearly 40 years Oxford ceased

to exist even in name as a place of medical education; another that, on the principle already referred to, namely, that the study of animals and plants should be considered as a part of the Oxford educational system, the subject of biology took its place side by side with the exact sciences in the newly formed School of Natural science. Thus it eventually became possible for Oxford students, after passing the First Public examination, to obtain a class, by proficiency in the sciences of observation. The third important result which followed from Acland's work at Christ Church was the establishment of the University Museum. The collection of specimens which Acland had brought from Edinburgh had grown during his tenure of the Christ Church Readership into a Museum which occupied several rooms and consisted of some 1,700 anatomical preparations. These were arranged by him for the use of students after the plan of the Museum of the College of Surgeons. The classification was Hunterian, *i.e.*, physiological, the parts of the animal body being grouped according to their uses. To the dissections and osteological preparations, which were for the most part the work of Mr. Robertson, were added a considerable number of specimens of marine animals,—the spoils of dredging expeditions on the south coast and at the Scilly Islands, in which Acland had the aid of Dr. Victor Carus, now Professor of Zoology at Leipzig. The Christ Church Museum was still further enriched by Dr. Rolleston, who succeeded Acland as Reader in 1858, so that when Rolleston was appointed to the newly constituted Linacre Professorship, it became apparent that the time had come for the University to take up the work that Christ Church had begun. Meanwhile Acland and others who had taken part in founding the new Natural Science School, had with great energy and perseverance promoted a Scheme for establishing an Institution in which provision could be made for all the studies connected with that School. The success of this scheme, which was in great measure due to his exertions, afforded the occasion for the supreme effort of his life, the erection of the Museum Building, and the transference thereto of the Christ Church Collection.

So long as Rolleston held the Linacre Professorship, the principle by which Dr. Acland was guided in the arrangement of the collection at Christ Church, namely, that it should be ordered on the plan of the Hunterian Museum of the College of Surgeons, in London, was not departed from; but after Rolleston's death, in 1881, a great change took place in the aspect of the Collection. The progress of Science required that the old comparative anatomy should give place to the new "Animal Morphology." The most valuable of the preparations may still be seen, but the Hunterian collection no longer exists. The great anatomist is still represented by Mr. Hope Pinker's beautiful statue, but of the "philosophic views" which Acland desired should be

introduced to the student by the arrangement described in his synopsis, published in 1853, there is now no indication. The change was inevitable, but those perhaps may be excused who, remembering the work done by Acland, Rolleston, and their coadjutors in the fifties, sixties, and seventies, regret that in giving place to the new order, some recollection of the old was not preserved.

With the completion of the Museum and the transference thereto of the Christ Church Collection, the great work which Acland had set himself to do for the advancement of science, was accomplished. He continued to take an active interest in the educational work of the Museum, and especially in the development and progress of the Anatomical Department, but opposed every effort to establish anything like a "Medical School" in the University.

The attitude assumed by Acland with reference to the teaching of Medicine during the long period which intervened between his appointment to the Regius Professorship, and the creation in 1890 of the Professorship of Human Anatomy, by which the University at last provided for the instruction of medical students, can be best understood by reference to his published writings, and particularly to the evidence he gave before the two University Commissions. When in the fifties he took a leading part in the establishment of the School of Natural Science, he expressed in a remarkable letter addressed by him to Mr. Gladstone (published as a pamphlet), the conviction that the effect of that change would be "to bring medical students to Oxford," and that unless this were the result, the school would probably fail. Again in the seventies, when he gave evidence before the Second Commission, he urged the immediate appointment of a Professorship of "Comparative Pathology" as the one thing needful for the completion of the system of instruction already in operation at the Museum. The fact that notwithstanding these decided opinions, he consistently opposed the very thing which he regarded as so conducive to the prosperity of the Natural Science School, namely, the introduction of the "Medical Student" into Oxford, seems at first sight difficult to explain. The real reason for his decided opposition to a "Medical School" was (to quote from the pamphlet above referred to) his apprehension of the "jeopardy of *substituting* professional for general education,"—his fear lest, if students were induced to engage too soon in professional studies, medical graduates would be sent from Oxford into the profession who had not received an Oxford education.

Sir Henry Acland's published writings were numerous. They related chiefly to academical or educational questions, or to subjects connected with Public Health or Sanitary administration. As perhaps the best specimen of his literary style, a biography may be referred to for which the Fellows of the Royal Society of forty years ago were

indebted to him—that of the President of the Society, the first Sir Benjamin Brodie. His most important contribution to the Science of which he was so successful an expositor was undoubtedly the "Synopsis of the Physiological Series" in the Christ Church Museum, in which he set forth in clear language the principles which had guided him in its arrangement.

Several friends who were Acland's pupils in the far-off days when he was Christ Church Reader, have given the writer their impressions of his lectures. They agree that his prelections were eminently suited to awaken interest in biological science, and that the lecturer was not only master of his subject, but was able to clothe in attractive language anatomical details which, had they been less skilfully handled, would have repelled his too fastidious auditors.

The preceding paragraphs may serve to inform the reader as to the work Acland accomplished as an academic teacher during the years that he held the Readership of Anatomy. After this period he devoted himself chiefly to the promotion of the general interests of the University, and to the furtherance of innumerable works of public utility both in the University and in the City. Although it was by these efforts that he was best known to the world, the scope of the present notice does not admit of more detailed reference to them. There were, however, two or three directions in which Acland's exertions contributed so materially to the advancement of science, that it will be proper to advert to them more fully.

For all but half a century (1851—1900) Acland held the University office of Radcliffe Librarian, and discharged its duties with singular ability and indefatigable industry. The Radcliffe Library contains, as I dare say most readers are aware, works relating to Mathematics, Physics, Chemistry, Biology (including Anthropology) and Geology. Acland was largly instrumental in bringing about the removal of the Library from the Camera Radcliffiana, which now forms part of the Bodleian, to the Museum Building, where rooms specially adapted for its reception had been prepared. The removal of the books afforded to Acland the opportunity of carrying out the organisation of the Library in a satisfactory way, and brought its resources within easy reach of persons engaged in the study of Natural Science whether as teachers or as students. All Oxford workers are deeply indebted to him for the exceptional advantages which the Library affords of ready access to the literature of their subjects.

Another way in which Acland contributed to the advancement of Science was by his efforts for the improvement of Medical Education, first as a Member and subsequently as President of the General Council of Medical Education. On this subject, his successor in that important office, Sir William Turner, has been good enough to set down some

notes, which he permits the writer to subjoin by way of conclusion to his own imperfect sketch.

As a Member and afterwards as President of the Council, "he took a leading part in the discussion of educational questions. His University training and environment kept continually before him the necessity of regarding Medicine as one of the learned professions, for which the special training required for its efficient practice must be based on a sound, general, and scientific education. In addition to his work in Oxford as a busy practitioner, Acland's attention had continually been drawn to the public relations of his profession. He kept in view that it had important duties to discharge to the State and to the community generally, and he took an active share in the discussions in the Council on educational questions bearing on the wider relations of his profession. As far back as 1868 he was appointed Chairman of a Committee to report on the steps proper to be taken for granting Diplomas or Certificates of Proficiency in State Medicine, and in providing for their inclusion in the Medical Register. In the course of time many of the examining authorities instituted Examinations on Public Heath and conferred diplomas, but it was not until the passing of the Medical Act, 1886, that these diplomas became registrable, and that the sanction of the State was then given to the possession of such diplomas, as a qualification to discharge the duties of a Medical Officer of Health.

"As President of the Council Sir Henry Acland was courteous in manner, graceful in speech, dignified in presence. His academic and social position, and the innate nobility of his nature, had from an early period of his life gained for him the friendship and confidence of the leaders of the medical profession, of statesmen of both parties, and others eminent in public life, and contributed in no small measure to ensure harmonious relations between the Medical Council and the departments of Government with which it is brought into official communication. From his urbanity and the consideration which he showed his colleagues he inspired in them a feeling of affectionate regard and respect."

J. B. S.

MAXWELL SIMPSON. 1815—1902.

On the 26th day of February, 1902, died at West Kensington an eminent chemist of the last generation.

Maxwell Simpson, B.A., M.B., M.D., LL.D. (Hon. Dub.), D.Sc., F.R.S., F.C.S., F.I.C., F.K.Q.C.P. (Dub.), Member of the Senate of the Queen's University, son of Thomas Simpson, Esq., of Beach Hill, Co. Armagh, Ireland, was born on March the 15th, 1815, and was educated at the famous private school of Dr. Henderson, at Newry, Co. Down, from whence he proceeded to Trinity College, Dublin. Dr. Lever, the celebrated novelist, an enthusiastic admirer of physiology, by means of his brilliant conversation, caused young Simpson to choose medicine as his profession. Accordingly, he attended besides the lectures of the arts course also lectures on medical subjects. His taste for medicine, however, did not improve with knowledge, and after four years of study he left Trinity College without a medical degree. He next went to London, where he stayed for some years. From London Simpson made once an excursion to Paris. On this occasion he attended a lecture of the celebrated chemist, Dumas, who, by his brilliant discourse, induced Simpson to choose chemistry as a profession. Accordingly, after his return to London, he attended the lectures of Prof. Graham, at University College, and also worked in the professor's laboratory.

Maxwell Simpson married, in 1845, Mary, the second daughter of the late Samuel Martin, of Loughorne, Co. Down, a lady who shared with him all the vicissitudes of life for 55 years, and to whom he was most affectionately attached. They settled in Dublin, where Simpson, in 1847, accepted the Chair of Chemistry in the Medical School of Park Street. Every lecturer at this Institution was expected to hold a medical degree. To satisfy this regulation he took up his medical studies again, passed the prescribed examinations, and took the degree of M.B. In the following year, 1848, he exchanged his chair in Park Street for one in the Medical School of St. Peter's Street, Dublin, where he delivered lectures before large classes till the spring of 1851.

Until the end of the first quarter of the last century instruction in practical chemistry could not be obtained at the Universities. Laboratories existed, but they were only intended for the private use of the professor. It is one of the merits of Liebig to have superseded this state of things, and to have founded, in 1824, at Giessen, a large laboratory for the instruction of students in practical chemistry. The School of Chemistry at Giessen soon became famous; students came from all parts of Europe to study chemistry under the guidance of

Liebig. This great success caused other Universities to adopt the system of Liebig, so that about the middle of the century many of the German Universities were provided with public laboratories. One of the best of these existed at Marburg, under the direction of Prof. Bunsen. Maxwell Simpson decided to go there and learn the Continental system of teaching the science of chemistry. The authorities of the Medical School in St. Peter's Street gave him leave of absence for three years, and he, with his whole family, left for Marburg in the spring of 1851. At Marburg a great disappointment awaited him. Prof. Bunsen had accepted a call to Breslau and had just left Marburg. His successor at the University, Prof. Kolbe, enjoyed a considerable reputation as a chemist, which induced Simpson to remain at Marburg till 1853. He then went to Heidelberg, where, in the meantime, Bunsen had accepted the Chair of Chemistry. At Heidelberg Simpson did his first original work.

Nitrogen in organic compounds was at the time usually determined according to the method of Will and Varrentrapp. This method is not applicable to cyanides and certain amides. The methods of Liebig and Dumas are not reliable when the compounds under examination are difficult to burn. The problem, to discover a method which could be used in all cases, remained to be solved. Simpson discovered such a method in Bunsen's laboratory.

His method is based on the same principles as those of Liebig and Dumas, but differs from theirs by the form of the apparatus, the use of mercuric oxide in place of cupric oxide, and the measurement of the gas over mercury instead of over water. ("Jour. Chem. Soc.," vi, 289.)

Fifty years have passed since the introduction of this method; other methods have since been recommended, but none more accurate or reliable than Simpson's. In 1854 he returned to Dublin, and took up again his lectures at St. Peter's Street School of Medicine. He discharged these duties till the end of the session, in 1856, when he finally gave up his lectureship, and proceeded with his family to Paris and commenced to work there in Wurtz's laboratory.

As early as 1843 it was recognised that the atoms of different elements are not of the same chemical value. Two atoms of chlorine were called an equivalent of chlorine, two atoms of aluminium three equivalents of aluminium. The chemical value of the oxygen atom used to be taken as the unit. As the knowledge of compound organic radicals was still in its infancy, their valency was not taken into consideration. The formulæ of the acids represented equivalent quantities, viz., such quantities of different acids as would neutralise the same quantity of a base.

As examples may be given the formulæ which Berzelius gave to acetic, tartaric, and citric acids :—

$C_4H_6O_3, H_2O$, Acetic acid
$C_4H_4O_5, H_2O$, Tartaric acid
$C_4H_4O_4, H_2O$, Citric acid

To Gerhardt is due the merit of having shown, in 1851, that the formulæ of acids ought to represent molecular and not equivalent weights, and of having given definitions of mono- and polybasic acids, which are still considered to be correct. These definitions, together with Gerhardt's-Williamson's theory of types, led to the recognition of the chemical values of compound radicals.

$$\text{Nitric acid} \left.\begin{matrix} NO_2 \\ H \end{matrix}\right\} O \qquad \left.\begin{matrix} C_2H_3O \\ H \end{matrix}\right\} O, \text{ Acetic acid.}$$

$$\text{Sulphuric acid} \left.\begin{matrix} SO_2 \\ H_2 \end{matrix}\right\} O_2 \qquad \left.\begin{matrix} C_4H_4O_2 \\ H_2 \end{matrix}\right\} O_2, \text{ Succinic acid.}$$

It is at once seen that the chemical value of SO_2 is twice that of NO_2, or, if acetyl is called monovalent, succinyl must be regarded as divalent. NO_2 and C_2H_3O each replace one atom of hydrogen in one molecule of water, SO_2 and $C_4H_4O_2$, each two atoms of hydrogen in two molecules of water. A monobasic acid is derived from one, a dibasic acid from two molecules in water.

The important discovery of the anhydrous acids R_2O and RR^1O, by Gerhardt, and the results of Berthelot's* investigation of the action of acids on glycerine, confirmed these views.

Berthelot concluded from his results that glycerine stood to a monovalent alcohol in the same relation as a tribasic acid did to a monobasic acid. Wurtz more fully explained this view. Hence, if there are alcohols of the structure of monobasic and tribasic acids, then there ought to be likewise alcohols corresponding to dibasic acids. Berzelius had pointed out, in 1839, that probably an alcohol $C_2H_6O_2$ could be prepared from ethylenic chloride $C_2H_4Cl_2$. No notice was taken of this suggestion until Wurtz, prompted by the above considerations, successfully carried out the idea of Berzelius by using $C_2H_4I_2$ instead of the chloride :—

$$\underset{\text{Ethylenic iodide}}{\underline{C_2H_4I_2}} \longrightarrow \underset{\text{Ethylenic Acetate}}{\underline{C_2H_4(C_2H_3O_2)_2}} \longrightarrow \underset{\text{Glycol}}{\underline{C_2H_4(OH)_2}} \longrightarrow \underset{\text{Oxalic Acid}}{\underline{C_2O_2(OH)_2}}$$

About the time when Simpson arrived in Paris Wurtz was engaged with the aforesaid investigations, which suggested the further question: can an alcohol of the structure of glycerine be prepared from $C_2H_3I_3$ or another halogen compound of vinyl ? Simpson undertook to answer

* Compt. Rend., xxxviii, 668.

this question. A series of very carefully executed experiments gave him only negative results. Accordingly, he concluded *that a glycerine,* $C_2H_6O_3$, *in the two-carbon group does not appear to exist.*

The view of the constitution of glycerine [$C_3H_5(OH)_3$], as pointed out before, had, however, not been strictly proved. Gerhardt* considered the formula $\left.\begin{matrix}C_3H_5O\\H_3\end{matrix}\right\}O_2$ more probable than the one given before. To decide which of the two is to be preferred, Simpson examined the action of acids on glycol. His results were analogous to those obtained by the action of acids on glycerine, consequently the structure of glycerine is: $C_3H_5\begin{matrix}-OH\\-OH,\\-OH\end{matrix}$ *analogous to that of glycol* ("Proc. R.S.," ix, 725, and x, 114.)

The experiments of Hofmann and Wurtz had established the important fact that the hydrogen of ammonia can be replaced by monovalent compound radicals. Cloez and Natanson had attempted the replacement of the hydrogen in ammonia by the divalent radical C_2H_4 without obtaining very satisfactory results. Simpson now commenced experiments with the view of substituting a trivalent compound radical for hydrogen in ammonia. He heated for this purpose allylic tribromide with an alcoholic solution of ammonia, expecting to obtain a triamine $(C_3H_5(NH_2)_3$. This expectation was not realised, *a secondary amine* $N\begin{matrix}\diagup(C_3H_4Br)_2\\\diagdown H\end{matrix}$ *being the result.* This base in interesting, because it yields picoline, C_6H_7N, by further treatment with alcoholic ammonia.†

Many of the halogen compounds of the olefines, which Simpson wanted for his experiments, were at the time hardly known at all, others only very imperfectly. He, accordingly, investigated more carefully the following: $C_3H_6Cl\,I$ ("P.,"‡ xii, 278); C_2H_4ClBr ("P.," xxvii, 118); $C_3H_5Cl_2Br$ ("P.," xxvii, 118); C_3H_6ClBr ("P.," xxvii, 118); CH_3CHBrI ("P.," xxvii, 424); $C_2H_3Br_3$ ("Phil. Mag.," (4), xiv, 544); and prepared for the first time; C_2H_4ClI ("P.," xi, 590, xii, 278); C_3H_6ClI ("P.," xii, 278); C_2H_3ClBrI ("P.," xiii, 540); $C_3H_5Cl_2I$ ("P.," xiii, 540); C_2H_4BrI ("P.," xxii, 51); $C_2H_3Br_2I$ ("P.," xxii, 51); C_3H_6BrI ("P.," xxii, 51); $C_3H_5Br_2Cl$ ("P.," xxvii, 118); $CH_3CHCl\,I$ ("P.," xxvii, 424).

This work repeatedly occupied him in the course of his scientific career.

The hydride and the chloride of acetyl react with great facility with many substances. Consequently, they may be expected to react

* "Traité Chim. Organique," iv, 699.

† "Phil Mag.," (4), xvi, 257. ‡ P = "Proc. Roy. Soc."

with each other, producing hydric chloride and $(C_2H_3O)_2$. But $(C_2H_3O)_2 = C_4H_6O_2$ = crotonic acid. Hence the question: is crotonic acid formed when aldehyde and acetylic chloride act on each other? Wurtz had already obtained in one experiment a compound of the two substances, which with water decomposed into the two components. He now suggested the repetition of the experiment to Simpson, who, however, could only confirm Wurtz's previous results. Experiments with acetylic chloride and the aldehyde $C_5H_{10}O$ produced likewise only a compound of the two.

At the conclusion of the experiments mentioned in the foregoing pages, about the end of the year 1859, Simpson left Paris and retained to Dublin, where, in his own house, he fitted up, in a back kitchen, a little laboratory, and there, in spite of many imperfections, he carried out some of his best work.

Dumas, Malaguti and Leblanc had shown that the ammonial salts of acetic-, benzoic-, valerianic-, and trichloracetic acids, by heating with phosphoric acid (P_2O_5), lose the elements of water and become converted into the corresponding nitriles. And, when the nitriles are heated with solutions of potassic hydrate, the corresponding ammonia salts are reformed. Kolbe and Frankland observed about the same time (1847) the formation of ammonic acetate by the action of potassic hydrate on methylic cyanide, and of ammonic propionate by a similar metamorphosis of ethylic cyanide. In these changes only monovalent radicals took part. Simpson undertook to investigate the behaviour of cyanides of divalent and trivalent compound radicals with hot solutions of potassic hydrate. He commenced with ethylenic cyanide; *the result was the potassium salt of ordinary succinic acid.*

$$C_2H_4Br_2 \longrightarrow C_2H_4Cy_2 \longrightarrow C_2H_4(CO_2H)_2$$

("P.," x, 574, xi, 190). Ethylidenic cyanide submitted to the same treatment was expected to yield potassic isosuccinate. Instead of this the common succinate was obtained. Propylenic cyanide and potassic hydrate solution produced *potassic pyrotartrate*:—

$$C_3H_6Br_2 \longrightarrow C_3H_6Cy_2 \longrightarrow C_3H_6(CO_2H)_2$$

The structure of the members of the oxalic acid series was made clear by these results. Allylic tricyanide boiled with potassic hydrate gave Simpson the *potassium salt of tricarballylic acid*:—

$$C_3H_5Br_3 \longrightarrow C_3H_5Cy_3 \longrightarrow C_3H_5(CO_2H)_3$$

("P.," xii, 236). This acid, which is related to aconitic acid as propionic is to acrylic acid, was first obtained by Dessaignes in impure condition by the action of sodium amalgam on aconitic acid. Kekulé suggested

that the acid of Simpson and the acid of Dessaignes were identical compounds. Wichelhaus proved this to be the case.

The real composition and the structure of tricarballylic acid were, however, inferred from Simpson's experiments. Tricarballylic acid is interesting in consequence of its relation to citric acid, the latter being the oxyacid of the former. A trivalent alcohol like glycerine can form three cyanides :—

$$C_3H_5(OH)_3 \longrightarrow C_3H_5(OH)_2Cy \longrightarrow C_3H_5(OH)Cy_2 \longrightarrow C_3H_5Cy_3$$

Each of these may be expected to produce with potassic hydrate solution a corresponding potassium salt. Simpson made the experiment with dichlorhydrin, and obtained potassic oxypyrotartrate (β oxy-glutaric acid ?) :—

$$C_3H_5(OH)Cl_2 \longrightarrow C_3H_5(OH)Cy_2 \longrightarrow \underset{\text{Oxypyrotartaric Acid}}{\underline{C_3H_5(OH)(CO_2H)_2}}$$

The compound $CH_3C\begin{matrix}-Cy\\-OH\\-H\end{matrix}$, obtained from aldehyde and hydro-cyanic acid gave Simpson and Gautier, under similar conditions, potassic lactate, thus confirming the synthesis of lactic acid from aldehyde and prussic acid by Strecker.

A mixture of alcohol, aldehyde and hydrochloric acid produce on standing monochlorether $\left.\begin{matrix}C_2H_5\\C_2H_4Cl\end{matrix}\right\}O$. As aldehyde and acetone are considered to possess an analogous constitution, Simpson expected a similar reaction to occur in a mixture of alcohol, acetone and hydric chloride, with the formation of the compound $C_5H_{11}ClO$. If in this compound the chlorine is replaced by cyanogen, and then the new cyanide boiled with potassic hydrate, the potassium salt of leucic acid might be formed and the synthesis of this acid thus be effected :—

$$C_5H_{11}OCl,\ C_5H_{11}OCy,\ C_5H_{11}O\,CO_2H = C_6H_{12}O_3.$$

A series of elaborate experiments gave Simpson not the expected results. The principal product was a derivative of mesitylic oxide :—

$$2(C_3H_6O) + 2HCl = C_6H_{12}OCl_2 + H_2O.$$

$$\text{and } C_6H_{12}OCl_2,\ C_6H_{12}OCy_2,\ C_6H_{12}OCy\,CO_2K.$$

Only one equivalent of cyanogen being converted by boiling potassic hydrate into the group CO_2H. The hydrogen salt $C_6H_{12}OCy\ CO_2H$, called mesitylic acid, was obtained in well-defined crystals, which have not been further examined by Simpson. ("P.," xvi, 364.)

In the year 1872 Maxwell Simpson was appointed Professor of Chemistry in the Queen's College, Cork. He now devoted himself enthusiastically to the performance of the duties of this appointment, and did his best by lectures and practical instruction to forward the scientific knowledge of his pupils. According to the testimony of the students, he was a most excellent teacher, second to none. The attention he paid to the duties of his Professorship, however, absorbed all his time and energies, so that he no longer was able to do original work. After the year 1872 his name occurs only once or twice in the scientific periodicals.

Commercial work Maxwell Simpson always refused. Liberal-minded, he always returned poor students the fees they had paid as members of his classes. It was only natural that a Professor like Maxwell Simpson should gain the respect and affection of all his students.

After working 20 years at Cork he retired and took up his abode at West Kensington, London, where he spent the last ten years of his life in quiet retirement, which was only broken by two painful events. First, he lost his eldest daughter, who was most devoted to her father, and then, only two years ago, Mrs. Simpson, the faithful wife who had shared, for more than 50 years, all his pleasures and sorrows.

H. D.

Rt. Hon. Sir RICHARD TEMPLE, Bart. 1826—1902.

Sir Richard Temple, who died March 15, 1902, was born in 1826, at the Nash, Kempsey, near Worcester. This property had belonged to his family, who were a younger branch of the Temples of Stowe, for many generations, and was ultimately inherited by him. He was educated at Rugby and Haileybury, and entered the Indian Civil Service in 1846. After serving for some years in the North-West Provinces and the Punjab, where he became, in 1854, secretary to Sir John (afterwards Lord) Lawrence, he was appointed, in 1860, member of a Special Financial Commission, and visited the different provinces of India to investigate their resources and revenue. His subsequent career is well known, and his official promotion was rapid. He became in succession, Chief Commissioner of the Central Provinces. Resident at Hyderabad, Foreign Secretary to the Government of India (1868), Financial Member of the Governor-General's Council (1868), Lieutenant-Governor of Bengal (1874), and Governor of Bombay (1877). In 1880 he retired from Indian service, and became a candidate for Parliament, at first unsuccessfully, but in 1885 he was elected member for Evesham in Worcestershire, and represented first that borough and

afterwards the Kingston division of Surrey until 1895. He was also a member of the London School Board from 1884 to 1894, and vice-chairman from 1885 to 1888.

The preceding list of the posts filled by Sir R. Temple is very far from complete. Few men have played more parts upon the world's stage, and very few have been more successful as officials. He was a man of great abilities, combined with unusual capacity for work, he was an admirable worker, a fairly good speaker and an accomplished artist, but his predominating talent was his wonderful energy. Many tales are told in India of great power of getting through work, and of his tact in dealing with difficult questions.

Of Sir R. Temple's labours as official and statesman it is unnecessary to write here, but a few instances may be mentioned in which he was able to promote scientific work, or to effect economic improvements by adopting scientific methods. The establishment and protection of reserved forests in India received much support from him ; he was first impressed with the importance of the subject when he was a member of the Financial Commission in 1860, and when Chief Commissioner of the Central Provinces in 1863, acting under the advice of the Inspector-General of Forests, Dr. (now Sir Dietrich) Brandis, he took steps, by adopting measures for the preservation of reserved forests from fires, and in other ways, which have resulted in the conversion of worthless scrub into valuable sources of timber supply. This beneficial work, carried out in spite of much opposition by both Europeans and natives, official and non-official, was afterwards continued by Sir R. Temple in Bengal and Bombay, and has become general throughout India. In Bengal also the reservation and protection of large tracts in the Sundarbans for forest supply was due to him. He also assisted in the establishing of cinchona plantations in Sikkim, and in the creation of a manufactory which now supplies quinine at a low price throughout Bengal, a great boon to a population decimated by malaria.

To the active aid of Sir R. Temple, when he was Lieut.-Governor of Bengal, is due the establishment of the flourishing Zoological Gardens of Calcutta. The Committee appointed by the Asiatic and Agri-Horticultural Societies had experienced the greatest difficulty in securing a good site, when the question was taken up and solved by the intervention of the Lieut.-Governor, who secured for zoological purposes the excellent garden now occupied at Alipore.

Sir R. Temple was the author of several works on India, he also published some autobiographical sketches, and an account of the House of Commons from his pen appeared in 1899. He was a Member of the Asiatic Society of Bengal from 1860, and a Fellow of the Royal Geographical Society from 1865. After his retirement from India, in 1880, he was for some years a member of the Council of the last-named

Society, and contributed several papers on Indian Geography to its Proceedings. But throughout his official career in India, and during his membership of Parliament, work of many kinds left him no time for scientific studies, and it was not till 1896, when he became a Privy Councillor, that he was elected a Fellow of the Royal Society. During the few years that remained of his life he was a frequent attendant at the Society's meetings. He was LL.D. of Cambridge and D.C.L. of Oxford, and his services to the State were recognised by his being made a Companion of the Star of India in 1866, K.C.S.I. in 1867, a Baronet in 1876, and G.C.S.I. in 1878.

W. T. B.

GEORGE FERGUSSON WILSON. 1822—1902.

George Fergusson Wilson was born at Wandsworth, of Scottish extraction. He died on the 28th of March, 1902, in the eightieth year of his age, at Weybridge Heath. He was a Fellow of the Linnean, the Chemical, and Royal Horticultural Societies, as well as of the Society of Arts, and was elected a Fellow of this Society in 1855.

The story of his life is instructive and encouraging. It is contained for the most part in a little autobiographical treatise, which he drew up for the instruction of his sons in 1876, under the title of "The Old Days of Price's Patent Candle Company."

It is not necessary in this place to do more than allude to the commercial features of this enterprise, nor to the philanthropic measures initiated in connection with it. Our concern lies with the development of chemical knowledge, and its successful application to a large manufacture.

The Company, of which Wilson was the Managing Director, for the first time not only brought good candle-light within the reach of a large class who could not previously afford it, but, in the collateral products of their manufacture, influenced two of the great staple manufactures of the country by the production of "cloth oil" and "spindle oil."

The Company were among the first to make practical use of superheated, low-pressure steam, as a consequence of which they were enabled to put pure glycerine on the market, and to manufacture pure palmitic acid, one result of which latter was the introduction of candles "that do not drop the grease."

George Wilson was taken from a solicitor's office, in 1840, to take part in the management of this Company. Knowing at first little or nothing about chemistry, but, having from the first a clear perception

of the value of such knowledge, he speedily devised experiments which ultimately led to important results. Wilson himself, in a lecture to the Society of Arts, says:—"Science once introduced has raised candle-making from a simple, clumsy, offensive, mechanical trade into a first-class chemical manufacture, one offering the widest field for applications of the highest chemistry. The time must soon, if it has not already, come, when a well-organised laboratory, and a thorough acquaintance with the works of the high scientific chemists, and even communication with some of themselves, will be considered necessary elements of candle-making success." This was written so long ago as 1856, when its cogency would not be so fully realised as it is now.

On his retirement from the management of this great concern, Wilson gave himself up enthusiastically to gardening as a hobby, being one of the first to adopt orchard-house culture on a considerable scale, and afterwards devoting himself to the culture of lilies and hardy plants generally. His garden was not a garden in the ordinary sense; it was a wood, a lake, a prairie, a rocky valley, where the plants did not appear to grow because they had been placed there, but because there they found the conditions most favourable for their growth. The art of the gardener was concealed, but none the less it was art based on accurate observation and continuous experiment, qualities gained in the laboratory, as he himself stated.

M. T. M.

ALFRED MARIE CORNU. 1841—1902.

Professor Alfred Marie Cornu, who died on the 12th April, 1902, was born in 1841 at Châteauneuf, and entered the École Polytechnique at the age of 19 years. Leaving it in 1864, he passed to the École des Mines, the diploma of which he received in 1866. But he did not remain long in the profession of engineering, being appointed in 1871 Professor of Physics in the École Polytechnique, an office which he held down to the day of his death. His brilliant career as a student was followed by one more brilliant as a teacher and investigator. Of his many contributions to original knowledge only a very brief outline can be given. His position at the École Polytechnique gave him, amidst the material surroundings of his laboratory, the leisure from routine so necessary for research and for the never-ending improvement of his courses of lectures to maintain them abreast of the advances of science. The beauty, the dignified ease and perfection, of his investigations, the perspicacity of his observations, the masterly reserve, so

to speak, of the scientific memoirs which from time to time he published, all bespeak a man of no ordinary capabilities—a master in his profession. Clear in his exposition of scientific matters, exquisitely clear alike in his experimental demonstrations and in the language in which he expounded their theory, he was as great in teaching as in research. His first publication was the thesis written for his doctorate upon the reflexion of light in crystalline media, in which he sought to perfect the theory of Fresnel by modifying the conditions at the limiting surface between the two media. This research exercised a notable influence upon his scientific life. Optics was his first love, and though he laboured successfully in other branches of experimental physics, it was to optics that he returned, and in the field of optics were achieved his greatest successes in physical investigation. The pages of the *Comptes Rendus* and of the *Journal de Physique* bear eloquent testimony to the activity and penetration of his mind. Already, from 1863 to 1865, while at the École des Mines, he had begun to contribute, to the Académie des Sciences, notes on the refraction and reflexion of light. Following up the work of Jamin, he later pursued the subjects of vitreous and metallic reflexion, and studied the connection between them. He showed that they were but parts of one and the same phenomenon, though affecting different regions of the spectrum, there being, as he demonstrated, a true continuity between them.

Soon after entering upon the duties of his chair, Cornu began, with laborious and patient preparation, those experiments upon the velocity of propagation of light which have become classical. Fizeau on the one hand, Foucault on the other, had already made determinations, each on his own lines. Foucault's value, then supposed to be the best, was $2{\cdot}98 \times 10^{10}$ in C.G.S. units. Cornu's results raised this figure to $3{\cdot}004 \times 10^{10}$ in vacuo, or $3{\cdot}0033 \times 10^{10}$ in air. His method, which was fundamentally the same as that of Fizeau, was applied to the transit of light over a total distance of 46 kilometres, or between two stations 23 kilometres apart, the one at the Observatoire in Paris, the other at Montlhéry. The instrumental perfection of his rotatory apparatus enabled him to observe up to the twenty-first extinction of the beam, thus securing a precision far in advance of that attained by Fizeau. For his determination of the velocity of light he was awarded the *prix Lacaze* in 1878, the same year in which his merits were recognised by his admission into the Académie des Sciences. He cherished the intention in later years of making a still more perfect determination by sending the light between Corsica and Mont Mounier, which is an annexe of the Observatory of Nice. In 1872 he wrote papers "On Electrostatic Measurement," dealing with the potential theories of Gauss and Green, then little known in France.

They are to be found in Vol. I. of the *Journal de Physique*, then recently founded by his friend d'Almeida.

For several years subsequently, and at different times, Cornu was occupied with researches on the spectrum. He measured the wave-lengths of the hydrogen rays with a precision previously unknown, enabling a comparison to be made between the values so obtained by experiment and the theoretical formulæ which had been proposed by Balmer and others to express them. The suggestions of Dr. Johnstone Stoney, and the later developments of Kayser and Runge, will not be forgotten in this relation. His special and searching inquiry into the ultra-violet solar spectrum is also memorable. He made observations on atmospheric absorption in the spectrum, using photographic methods, at his country house at Courtenay, where he spent most of his vacations. He devised an elegant modification of the slit apparatus to enable simultaneous observations to be made of light from the two ends of a diameter of the sun's surface, the advancing and the retreating, and thus, by an application of Doppler's principle, was able effectually to pick out those lines which were of solar origin from those due to absorption in the stationary atmosphere of the earth. He was able to fix the inferior limit to the ultra-violet end of the spectrum, so far as it is visible at low elevations, and found that in the laboratory air is opaque to ultra-violet waves of a lesser wave-length than $0{\cdot}185\mu$. His work on meteorological optics has thus been summarised by M. Guillaume: "Such researches, in the course of which he was often led to a scrutiny of the sky, could not fail to draw his attention to the optical phenomena of the atmosphere, the study of which, though energetically pursued by the French physicists of last century, is to-day somewhat neglected. The splendid glows which were observed in the sky toward the end of 1883 furnished to Cornu an occasion to utilise the profound knowledge which he possessed of the phenomena of optics. He showed that the twilight glow, which at that time gave such marvellous charm to the sunsets, was due to a diffraction caused by fine powders, and it became evident that the formidable volcanic explosion of Krakatoa was the prime cause of it."

To Cornu we owe some admirable studies upon the conditions for achromatism in the phenomena of interference; a solution of the problem of photometry of polarised light; and researches on the focal anomalies of diffraction gratings. Shortly after the announcement of the Zeeman phenomenon, Cornu discovered that the line D, under magnetisation in the normal direction, is decomposed into four components. He also published an elegant experimental method for the investigation of the optical constants of lens systems. He devised the optical lever for the measurement of the curvatures of lenses; and he perfected the Jellett prism for polarimetric work. To him is

due the elegant geometrical construction in which spirals are applied to express graphically the relative intensities of the light in diffraction images. His preference for geometrical demonstrations of theorems, which might otherwise be hidden under a burden of analytical symbols, was well known. He worked acoustics in conjunction with M. Mercadier, and investigated the values of musical intervals in the case of melody and in the case of harmony, which it is known are not necessarily coincident. He examined experimentally the torsional vibrations which accompany the transverse vibrations of violin strings. In conjunction with M. Baille, he redetermined the constant of gravitation. He was occupied, too, with the problems of synchronisation of two resonant systems capable of vibration under elastic forces, these memoirs being published in 1888 and 1889, the second of them including the application of his ideas to the synchronisation of clocks for the distribution of time. His plan was closely akin to that of Wheatstone, depending on the sending, at every second, of feeble induction currents generated by the movement of a magnet attached to the pendulum of a master clock. In 1884 he reported on the electric transmission of power by M. Marcel Deprez on the Chemin de Fer du Nord. He took part in the first electrical congress at Paris in 1881. In 1886 he became a member of the Bureau des Longitudes, and of the International Bureau of Weights and Measures. For the former body, in which he took great interest, he did much to perfect the "Annuaire," to which he contributed some exceedingly valuable and authoritative essays on electric phenomena from the modern standpoint, on star spectra, on electric generators, and on polyphase currents. On the International Bureau of Weights and Measures he worked at the construction of the new standards, insisting, against considerable opposition at first, on the advantage of adopting a highly polished surface upon which to engrave the fiducial marks in the new metre standards. To his pen as reporter, after the death of M. Tresca, is due the report of the International Bureau, recording the transition from the old "mètre des archives" to the "prototype provisoire," which in turn led to the "mètre prototype international."

Cornu was twice President of the Société de Physique, of which, indeed, he was one of the foundation members. He took an active interest in its meetings, and contributed much to its success. He was also President of the Académie des Sciences; and by general consent was elected to preside over the International Congress of Physics in 1900. He was elected a Foreign Member of the Royal Society in 1884, and had previously, in 1878, received the Rumford Medal for his work on the velocity of light. He was also an Honorary Member of the Physical Society of London. At least twice he gave Friday evening discourses at the Royal Institution; the last of these, in 1895,

being "On the Physical Phenomena of the High Regions of the Atmosphere."

In 1899 he delivered, with delighted eloquence and learned ease, the Rede lecture at Cambridge, "On the Wave-Theory of Light and its Influence on Modern Physics." On this occasion, which was at the time of the jubilee celebration of Sir George Stokes, he received the honorary degree of Doctor of Science.

In Cornu, France has lost one of her most distinguished men of science, and one who, not only as investigator, but as teacher and wise counsellor, had won universal esteem and respect. A true follower of the high traditions of France in the pursuit of science, and a passionate follower of Arago, Biot, Fresnel, and Fizeau, he was in his own person much more than this. He was the ideal of a well-equipped, well-balanced, intellectual leader in scientific thought; at the same time a man of action, and an artist in words.

S. P. T.

JOHN HALL GLADSTONE. 1827—1902.

John Hall Gladstone was born at 7, Chatham Place West, Hackney, on March 7, 1827. He was the eldest of three brothers, and at the time of his birth, his father, John Gladstone, was junior partner in the firm of Cook and Gladstone, wholesale drapers and warehousemen in Cheapside, and afterwards in St. Paul's Churchyard.

The Gladstone family belonged to Kelso, in Roxburghshire, where, as the parish registers show, they had been established since 1645. John Hall Gladstone's immediate ancestors were damask weavers, his grandfather being what was known as a master-weaver. His father came to London in 1815, and, in the early part of the following year, became a shopboy in Mr. Cook's establishment, but soon rose to be traveller and buyer, and in 1824 was taken into partnership, when he married his cousin, Alison Hall, whose father had a drapery establishment in Bishopsgate Street. He prospered in his business, and eventually removed to Stockwell Lodge, a house now forming part of the South London Fever Hospital. John Hall Gladstone with his brothers, was educated entirely at home under tutors. His father, having amassed a considerable fortune, retired from business in 1842, and spent some time on the Continent with his family and in the society of his friends, Mr. and Mrs. Tilt, whose daughter May, six years later, became John Hall Gladstone s wife.

Even in early boyhood John Hall Gladstone showed a strong bias

towards natural science, and in 1844 he elected to take up science as a calling, and went to University College to attend the chemical lectures of Graham, and to work in his private laboratory. Whilst here he gained a Gold Medal for original research, and published his first contribution to scientific literature in the form of a paper on Guncotton and Xyloidine. In 1847 he went to Giessen University to work under Liebig; here he took his degree as Doctor of Philosophy, and returned to London in the following year. In 1850 he was appointed Lecturer in Chemistry at St. Thomas's Hospital, and in 1853, at the age of 26, he was elected into the Royal Society. Six years later he was made a Member of the Royal Commission on Lighthouses, Buoys, and Beacons, and from 1864 to 1868 he served as a Member of the Guncotton Committee, appointed by the War Office. He held the Fullerian Professorship of Chemistry at the Royal Institution from 1874 to 1877, and was President of the Physical Society, of which he was one of the original founders, in the year of its formation in 1874, and was President of the Chemical Society, of which he had been a Member since 1848, in 1877—79. He was one of the six past Presidents of the last-named Society who could boast of a membership of over fifty years, and in whose honour a banquet was given in 1898.

As a man of science, Dr. Gladstone will be mainly remembered for his share in the early development of Physical Chemistry, and especially of that portion of it which is concerned with the relations of Chemistry to Optics. He was one of the earliest workers in Spectroscopy and on the application of the prism to chemical analysis, and he was the first to detect the remarkable optical behaviour of didymium and its solutions. He published a series of papers on the solar spectrum, one of them in conjunction with Sir David Brewster, and on the spectra of gases. He worked also on fluorescence and phosphorescence, on chromatic phenomena, and on circular polarisation; on the influence of temperature on the refraction of light, and on the refraction equivalents of the elements. Some of his papers on these subjects were published in association with the Rev. J. P. Dale. He was among the earliest to trace the connection between the chemical constitution of a substance and its refractive and dispersive powers.

Questions of chemical dynamics and on the causes and conditions of chemical change occupied him at various times throughout the whole period of his life as an investigator, and he published a number of papers on the reciprocal decomposition of salts and on the conditions governing their stability.

In the early part of his career he did a considerable amount of work in pure chemistry, particularly in inorganic chemistry, and especially on the haloid compounds of phosphorus and their ammoniacal

derivatives, on nitrogen chlorophosphide, on the so-called nitrogen iodides, and on pyrophosphoric acid and its amides, mostly alone, but partly in conjunction with Mr. J. D. Holmes. After Mr. Holmes' death, he worked in collaboration with Mr. Alfred Tribe. The discovery of the copper-zinc couple in 1872, and the study of its action on organic substances, constitute, perhaps, the most important result of this co-operation. For these researches he was awarded, in 1897, the Davy Medal.

Dr. Gladstone was well acquainted with Faraday. Indeed, there was much in common between the two men, and their intimacy developed into a firm and lasting friendship. After Faraday's death, Dr. Gladstone put together his reminiscences of his friend in the form of a biographical notice, "The Biography of Michael Faraday, London, 1872," which was one of the most popular and most widely read accounts of the career of that illustrious philosopher.

Although ardently attached to science, and keenly interested in its progress, much of Dr. Gladstone's intellectual energy was spent in other pursuits. Throughout the whole of his life he was engaged in philanthropic, educational, and religious movements. Very early in his career he became connected with the British and Foreign School Society, and soon after the formation of the Young Men's Christian Association he joined the parent Society, and served on the Committee for some years, and when the first World's Conference met in Paris in 1855, he was one of the representatives of the London Associations, and also at the first British Conference, held at Leeds in 1858. He was a Vice-President of the National Council from the time of its formation, and took a great interest in its work at home and abroad.

Members of the British Association for the Advancement of Science will remember that Dr. Gladstone, who was a constant attendant at its gatherings, annually convened a religious meeting, as a practical expression of his views concerning the relation of science to religion. As a Member of the Christian Evidence Society, in whose work he continued to take the liveliest interest to the very day of his death, he published two lectures, one on "Points of Supposed Collision between the Scriptures and Natural Science," and the second, on "Miracles as Credentials of a Revelation."

Dr. Gladstone, who was an ardent Liberal in politics, was frequently solicited to enter Parliament, and in 1868 he unsuccessfully contested the borough of York. If returned, he had intended to throw himself into the educational struggle which was to culminate in the passage of Mr. Forster's measure in 1870. Indeed, he will long be remembered for his services to the cause of education.

From 1873 to 1894 he was a Member of the School Board for

London for the Chelsea District; for three years he was Vice-Chairman of the Board, and for many years he was Chairman of the Books and Apparatus Sub-Committee. As a practical educationist his consistent aim was "to improve the methods of instruction, and to arrange for due provision in the schools for carrying out the more important branches of education—those that would best fit the children for the needs of later life, and give them the best attainable knowledge of the world and of the forces around them." To this end he set himself to investigate the school systems in various Continental countries, and in Canada, the United States, and in Algeria.

Dr. Gladstone was an expert phonographer, and his intimate acquaintance with the art was no doubt the reason why he so persistently advocated the necessity for a reform in English spelling. In 1876 he succeeded in inducing the London School Board to pass, by a large majority, a resolution affirming that a great difficulty was placed in the way of education by the present method of spelling, and suggesting that a Royal Commission should be appointed to consider the best means of reforming and simplifying it. The topic was extensively discussed, and a considerable number of the provincial School Boards were induced, in spite of the opposition of the late Mr. Firth (then Chairman of the London School Board), to join in a memorial to the Committee of Council on Education in favour of the reform. Dr. Gladstone helped the movement by the publication of a small work on "Spelling Reform from an Educational Point of View," which went through several editions, and he induced the now defunct Social Science Association to take up the subject. The outcome of this was the foundation, in 1879, of the Spelling Reform Association, which continued to press upon the Education Department the need for inquiry. The attitude of Sir Francis Sandford was consistently unfavourable, and but little is heard to-day of the question of phonetic spelling. Dr. Gladstone was, however, successful in helping to abolish the use of the ordinary spelling-books, and in making shorthand a subject of tuition in the day and evening schools of the Board.

He was further instrumental in forwarding the movement for manual instruction in Board Schools, and in securing greater attention to technical training. He had a firm belief in the value of object-lessons, and in 1883 published a lecture on "Object Teaching."

During the religious controversy, which was in full swing at the Board in 1894, in which year he did not seek re-election, he spoke strongly against the action of those who attacked the system of religious instruction adopted in the schools of the Board, as the result of the Cowper-Temple Clause of the Act of 1870.

At the time of his death he was an Almoner of Christ's Hospital,

and took great interest in the re-arrangement of the School consequent upon its removal to Horsham.

In recognition of his services to education, he was made an Honorary Fellow of the College of Preceptors. He was made an Honorary D.Sc. at the Tercentenary of Trinity College, Dublin, in 1892.

On Monday, October 6, 1902, he had attended a Meeting of the Christian Evidence Society, and returned to his residence in Pembridge Square, in his usual health, at about 6 p.m. At 7.30 his body was found, lifeless, in his study. He had been stricken with heart-failure. He was buried, on the following Friday, in Kensal Green Cemetery.

He was twice married. His first wife died in 1864, in which year he lost also his eldest daughter and only son. His second wife, Margaret, to whom he was married in 1869, was the daughter of the late Rev. Dr. King and a niece of Lord Kelvin's.

A man of singular modesty; quiet, gentle, and unobtrusive; urbane, courteous, and conciliatory in manner; earnest in well-doing; helpful and considerate to others, and of transparent integrity; his kindly genial presence will long be missed in those gatherings of men of science in which he found, during upwards of half a century, the great pleasure of his life.

T. E. T.

Sir WILLIAM CHANDLER ROBERTS-AUSTEN, K.C.B.
1843—1902.

Sir William Chandler Roberts-Austen, K.C.B., who died on November 22, 1902, was born in 1843. His father, George Roberts, was of Welsh descent, whilst his mother, Maria Louisa, belonged to the Kentish family of Chandler, which intermarried with the Austens. In 1885, at the request of his uncle, the late Major Austen, J.P., of Haffenden and Camborne, in Kent, he obtained Royal licence to take the name of Austen.

At the age of 18 he entered the Royal School of Mines, with the intention of becoming a mining engineer, but after obtaining the Associateship of the School he was engaged by Graham, then Master of the Mint, in the capacity of a private assistant. On Graham's death, in 1869, the Department was reorganised in accordance with the provisions of the Coinage Act of the following year, and in conformity with the recommendations of the Royal Commission which had been appointed to inquire into the administration of the

Mint as far back as 1848. Under that Act the Chancellor of the Exchequer for the time being became Master, Worker, and Warden of the Royal Mint. No salary was attached to the office, but it was provided that all its duties should be performed and exercised by his "sufficient deputy." In order to provide for the efficient discharge of the scientific work devolving on the Mint, a new post—that of "Chemist of the Mint"—was created, and Roberts was selected to fill it, being appointed by Treasury Minute of January 7, 1870. At this time the assays on gold and silver bullion received for coinage were performed within the Department, whereas the assays of coinage bars and finished coin were entrusted to certain eminent chemists, known as "non-resident assayers." The death of Dr. W. Allen Miller, one of the non-resident assayers of the Mint, towards the end of 1870, afforded an opportunity for reconsidering the general system on which the assay work of the Department was conducted, with the result that the practice of employing non-resident assayers was discontinued. This led to the appointment of Roberts as a second assayer in the Mint, whilst retaining his post as chemist. This arrangement was maintained until 1882, when the assay work was concentrated in one office, and Roberts was appointed to the amalgamated post of "Chemist and Assayer," the separate post of chemist being abolished. This office he held up to the time of his death, practically no change having been made in the organisation of the Assay Department for the last twenty years.

It is impossible to enumerate here the many technical points connected with the metallic currency to which Sir William Roberts-Austen's attention was directed during the thirty-three years which have elapsed since he became officially connected with the Mint. These are described in more or less detail in the memoranda he was called upon to supply each year for publication in the Annual Reports of the Deputy Master and Comptroller of the Royal Mint, which have been regularly presented to Parliament since 1870.

Some of the more important of these questions, with the years in which they came up for special consideration, are enumerated below:—

Chemical and metallurgical operations in European Mints	1870
Treatment of brittle gold	1870–1
Assay by means of the spectroscope, in conjunction with Sir Norman Lockyer	1872–4
Ancient trial plates of gold and silver	1873
Liquation in alloys	1874
Density of gold copper alloys	1877–8

The induction balance, in conjunction with its inventor, Prof. Hughes	1880
Steel for the manufacture of dies	1881, 1897
Hardening of steel	1882
Density of metals in fluid state	1881–2
Method of reporting gold assays	1882
Rate of wear of coins, in conjunction with Mr. R. A. Hill	1883–4
Art of casting metals	1885
Report on Mints and Assay Offices of the United States, in conjunction with the Deputy Master	1885
Electro-deposition of iron	1886, 1901
Cost of production of silver	1888
Eutectic alloys	1890
Wear of gold coins	1891
Diffusion of metals	1895
Treatment of the surface of silver and bronze medals	1897
Standard trial plates	1899
Bronze alloys for medals	1900

On the death of Sir Horace Seymour, the late Deputy Master of the Mint, in June last, Sir William Roberts-Austen was appointed to fill the office *ad interim*, or until his own official connection with the Mint should be severed by resignation. This he had intended should take effect in the spring of the coming year. It may be said, therefore, that Sir William Roberts-Austen has, at one time or other, filled every office in the Mint which a man of his order could aspire to. And no more convincing testimony to the manner in which he discharged his official duties, and no more eloquent proof of how he acquitted himself under the great responsibilities of his position, could be adduced than this single fact.

Roberts-Austen always cherished, as one of the most treasured memories of his life, the recollection of his early association with the Royal School of Mines, and there was probably no one position he coveted more than its chair of metallurgy, and no incident in his career which gave him more pleasure than his appointment, in 1880, to that chair, in succession to the late Dr. Percy. It was the wish of his heart, had he been spared, that, after his retirement from the Mint, he might spend his remaining years—or so many of them as the regulations of the Department would have allowed him to spend—in the service of the School. It was possible that he cherished the hope that the erection of the new buildings on the other side of Exhibition Road might have afforded him the opportunity he had

long desired—that of creating and equipping a metallurgical laboratory which should be worthy of this country and of an Empire whose sons are engaged in metallurgical work in almost every part of the globe. But if this was not to be, he has at least erected a monument to himself in the record of his past achievement; in the thoroughness and fulness of his teaching; in the scientific enthusiasm with which he sought to lay bare and illumine the problems of physical metallurgy. During the two-and-twenty years he held his chair, he trained a succession of men holding important positions at home and in many parts of the world, who are grateful to him for the stimulating influence of his teaching, who will recall many acts of personal kindness and goodwill, and who, now that his place in the subterranean lecture-room he loved so well, and in which, with all the quickening zeal of a born teacher, he had spent some of the happiest hours of his life, knows him no more, will mourn his loss as that of a dear friend, and will continue to cherish his memory and recall the many kindly traits of head and heart which characterised him.

In the outset of his career as an investigator, Roberts-Austen occupied himself with a number of minor problems in inorganic chemistry, and there is little continuity of thought or effort to be traced in much of his 'prentice work. But there is invariably the note of originality. All his life through he was strongly attracted by what is odd, uncommon, or *bizarre.* Perhaps it was the influence of the Celtic blood which ran in his veins which predisposed him to the mysticism which was undoubtedly a feature of his character. Had he lived three hundred years ago, he would have been a typical alchemist, and have spent all the skill and energy he showed in assaying and minting gold in vain attempts to make it. Science, however, would certainly have been the richer for his efforts, for he was a very acute observer, and although occasionally his preconceptions were liable to run away with him for a time, especially in the direction of scientific heterodoxy, he was staunchly loyal to his facts. Much of his work was influenced by his strong artistic sense and by his passionate regard for beauty of form or colour. The secrets of Oriental metallurgy had a singular fascination for him. He would literally gloat over some triumph of Japanese art, and the discovery of by what kind of "pickle," or by what kind of treatment, the lustre or colour or effect on a bronze had been obtained was a delight to him as intense as if he had lighted upon a new metal. The artistic side of his nature found frequent exercise in his work at the Mint, especially in medal-striking. He occasionally chafed under the necessity of having to make use of designs for which he had no sympathy, but he had a real delight in reproducing, with the highest degree of excellence that the resources at his command permitted,

artistic work which his trained judgment and fine critical insight perceived to be sound and true. Indeed, this sense of "finish" and feeling for artistic excellence, amounting almost to fastidiousness, was seen, not only in his actual manipulative work and in the way in which he arranged and perfected his experimental illustration, but in the manner and form in which he put together and presented any account of his labours. His lectures at the Royal Institution were invariably illustrations of this. Perhaps no man since Tyndall's day ever handled a Friday evening discourse with more tact and skill than did Roberts-Austen. His matter was always fresh, his experiments always interesting, frequently daring, and occasionally strikingly original. He never tried to be rhetorical or pretended to be eloquent, but there was a certain literary finish in his sayings, a feeling for epigram, a sense of proportion in arrangement, and at times a quiet, subdued touch of humour which altogether made him delightful to listen to.

The Royal Society's Catalogue of Scientific Papers records that Roberts-Austen published some two dozen papers, for the most part singly, but occasionally in collaboration with Sir Norman Lockyer, Prof. Osmond and the late Dr. Alder Wright.

These papers made their appearance in the *Philosophical Transactions*, in the *Proceedings* of the Royal Society, in the *Journal* of the Chemical Society, in the *Philosophical Magazine* and in the Reports of the British Association for the Advancement of Science. They practically all relate to metallurgical problems, or are connected with the scientific side of his duties as an officer of the Mint. They deal with the spectroscopic characters of alloys, the physical and chemical nature of alloys, the structure of metals and the connection between the properties of metals and the periodic law, and the nature of the hydrogen occluded by palladium and by electro-deposited iron.

In 1890, at the request of the Alloys Research Committee of the Institution of Mechanical Engineers, he began to investigate the effects of small admixture of certain elements on the mechanical and physical properties of the common metals and their alloys. Whilst engaged on that work he devised the recording pyrometer, an instrument which has proved to be of the greatest value, not only to the investigator of pure science, but also to the practical metallurgist in recording the temperature of annealing and other furnaces, and that of the blast in blast-furnaces. The results of these investigations are embodied in reports to the Institution of Mechanical Engineers, which afford a mass of valuable information concerning the structure of metals and their alloys, and their behaviour under varying physical conditions.

It was in the domain of physical metallurgy that he specially excelled, and by his unwearied energy, by his skill and resourcefulness

as an experimentalist, he has succeeded in clearing up much that was vague and imperfectly understood in that field of inquiry.

He is the author of an "Introduction to the Study of Metallurgy," which has been characterised as a masterly guide to a knowledge of the principles on which the art is based.

This bald outline of Roberts-Austen's scientific work gives, however, a very inadequate idea of his diligence as a man of science or of the influence which he exerted on the progress of science. Such work as he engaged in was, from its very nature, time-consuming, and results were only obtained slowly and laboriously. From his official position, too, and by reason of his attainments, he was constantly called upon to serve upon committees, councils and commissions, into the work of which he never failed to throw himself with characteristic ardour and self-sacrifice. In 1885 he was a member of the executive council of the Inventions Exhibition. In 1889 he served on the British executive council of the Paris Exhibition, and in 1893 on that of the Chicago Exhibition. In the former year he received the Cross of Chevalier of the Legion of Honour.

He sat with the writer on the Treasury Committee which preceded the establishment of the National Physical Laboratory, and he was also a member of the Board of Trade Committee appointed to inquire into the deterioration of steel rails during use in railway traction.

Since 1899 he had been a member of the Explosives Committee appointed to investigate explosives for use in the Army and Navy and material for the construction of guns.

Concurrently with the services he rendered to the State, as a public servant, he did his fair share of labour in the organisation of scientific work as an executive officer of various scientific societies. He joined the Chemical Society in 1866, and served on its council in 1879—81, and became a vice-president in 1895—98.

In 1875 he was elected into the Royal Society, and served as a member of Council in 1890—92, and was a member and chairman of some of its committees. He was one of the founders of the Physical Society, of which he was also a vice-president, and was an active member of the Society of Arts, of which he was a member of council and vice-president at the time of his death. He was also an honorary member of the Institution of Civil Engineers, of the Institution of Mechanical Engineers, and of the Institution of Mining and Metallurgy.

He was elected president of the Iron and Steel Institute in 1899, and held office until 1901.

In 1888 he was made a C.B., and received his knighthood in the order in 1899.

The University of Durham made him a D.C.L. in 1897, and a year or two later he received the honorary degree of D.Sc. from the Victoria University.

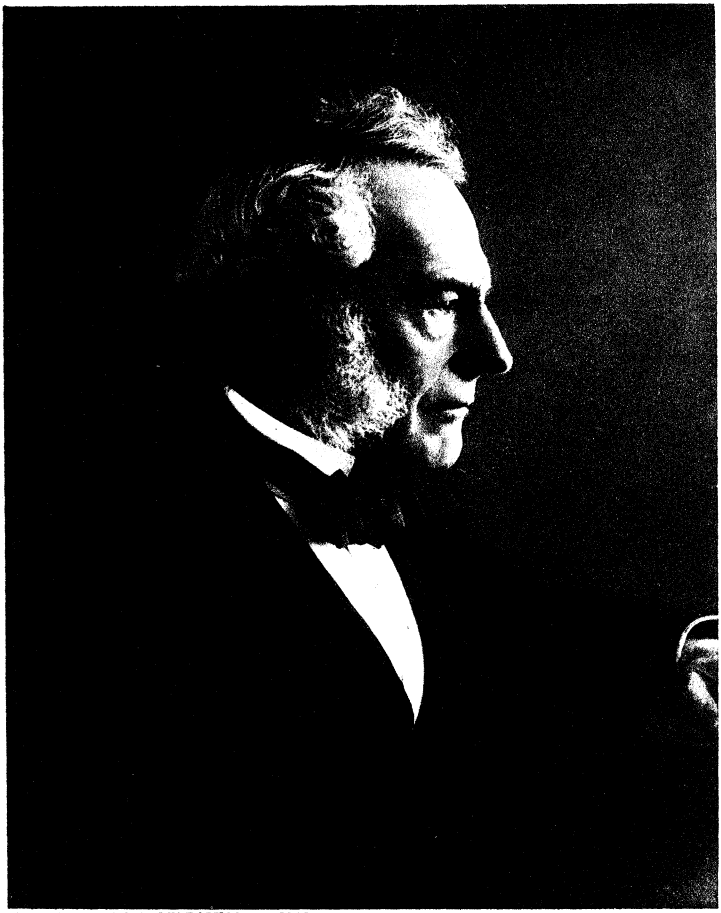
He was a constant attendant of the meetings of the British Association, and served as one of the general secretaries of the Council from 1897 to the year of his death.

His last public lecture was the James Forrest Lecture on "Metallurgy in Relation to Engineering," given to the Institution of Civil Engineers on April 23. In special lectures of this kind Roberts-Austen excelled. They cost him considerable effort, for he spared no trouble to make the occasion worthy of himself and of his subject, and he had his reward in the grateful appreciation of his auditory. A notable example of the quality of his work as a lecturer is seen in the Graham lecture on "Molecular Movement," which he gave to the Philosophical Society of Glasgow in 1879.

Indeed, no man discharged more faithfully, more honourably, or more religiously the obligations he had incurred, or which, by virtue of his position, were thrust upon him. It may be truthfully said of him that whatsoever his hand found to do he did it with all his might.

Some years ago Roberts-Austen acquired a small place at Chilworth, near Guildford, to which he would repair with Lady Roberts-Austen on all possible occasions. It never meant idleness to him, but there is no doubt that the occasional change from the atmosphere of Tower Hill to the breezy, invigorating air of a Surrey common had some effect in preserving him from the constant inroad he made upon his physical and mental energy. His social instincts made him a good neighbour, and he spent time and no inconsiderable amount of money in improving the lot of those around him. There was one side of his character of which only those who knew him well were made fully aware. It is reflected, however, in the beautifully decorated little chapel which he erected near his house for the benefit of the district, and in which he was wont to minister nearly every Sunday.

T. E. T.



G. G. Stokes

OBITUARY NOTICES

OF

FELLOWS DECEASED.

(PART iii.)

SIR GEORGE GABRIEL STOKES, BART. 1819—1903.

In common with so many distinguished men Sir George Stokes was the son of a clergyman. His father, Gabriel Stokes, who was Rector of Skreen, County Sligo, married Elizabeth Haughton, and by her had eight children, of whom George was the youngest. The family can be traced back to Gabriel Stokes, born 1680, a well-known engineer in Dublin and Deputy Surveyor General of Ireland, who wrote a treatise on Hydrostatics and designed the Pigeon House Wall in Dublin Harbour. This Gabriel Stokes married Elizabeth King in 1711 and among his descendants in collateral branches there are several mathematicians, a Regius Professor of Greek, two Regius Professors of Medicine, and a large sprinkling of Scholars of Trinity College, Dublin. In more recent times Margaret Stokes, the Irish antiquary, and the Celtic scholar, Whitley Stokes, children of the eminent physician, Dr. William Stokes, have, among others, shed lustre on the name.

The home at Skreen was a very happy one. In the excellent sea air the children grew up with strong bodies and active minds. Of course great economy had to be practised to meet the educational needs of the family; but in the Arcadian simplicity of a place where chickens cost sixpence and eggs were five or six a penny, it was easy to feed them. They were all deeply attached to their mother, a beautiful and severe woman who made herself feared as well as loved.

Stokes was taught at home; he learnt reading and arithmetic from the Parish Clerk, and Latin from his father who had been a Scholar of Trinity College, Dublin. The former used to tell with great delight that Master George had made out for himself new ways of doing

sums, better than the book. In 1832, at 13 years of age, he was sent to Dr. Walls' school in Dublin; and in 1835 for two years to Bristol College, of which Dr. Jerrard was Principal. There is a tradition that he did many of the propositions of Euclid, as problems, without looking at the book. He considered that he owed much to the teaching of Francis Newman, brother of the Cardinal, then mathematical master at Bristol College, and a man of great charm of character as well as of unusual attainments.

On the first crossing to Bristol the ship nearly foundered; and his brother, who was escorting him, was much impressed by his coolness in face of danger. His habit, often remarked in after life, of answering with a plain "yes" or "no," when something more elaborate was expected, is supposed to date from this time, when his brothers chaffed him and warned him that if he gave "long Irish answers" he would be laughed at by his school-fellows.

It is surprising to learn that as a little boy he was passionate, and liable to violent, if transitory, fits of rage. So completely was this tendency overcome that in after life his temper was remarkably calm and even. He was fond of botany, and when about sixteen or seventeen, collected butterflies and caterpillars. It is narrated that one day while on a walk with a friend he failed to return the salutation of some ladies of his acquaintance, afterwards explaining his conduct by remarking that his hat was full of beetles!

In 1837, the year of Queen Victoria's accession, he commenced residence at Cambridge, where he was to find his home, almost without intermission, for sixty-six years. In those days sports were not the fashion for reading men, but he was a good walker, and astonished his contemporaries by the strength of his swimming. Even at a much later date he enjoyed encounters with wind and waves in his summer holidays on the north coast of Ireland. At Pembroke College his mathematical abilities soon attracted attention, and in 1841 he graduated as Senior Wrangler and first Smith's Prizeman. In the same year he was elected Fellow of his College.

After his degree, Stokes lost little time in applying his mathematical powers to original investigation. During the next three or four years there appeared papers dealing with hydrodynamics, wherein are contained many standard theorems. As an example of these novelties, the use of a stream-function in three dimensions may be cited. It had already been shown by Lagrange and Earnshaw that in the motion of an incompressible fluid in *two dimensions* the component velocities at any point may be expressed by means of a function known as the stream-function, from the property that it remains constant along any line of motion. It was further shown by Stokes that there is a similar function in three dimensions when the motion is

symmetrical with respect to an axis. For many years the papers, now under consideration, were very little known abroad, and some of the results are still attributed by Continental writers to other authors.

A memoir of great importance on the "Friction of Fluids in Motion, etc.," followed a little later (1845). The most general motion of a medium in the neighbourhood of any point is analysed into three constituents—a motion of pure translation, one of pure rotation, and one of pure strain. These results are now very familiar; it may assist us to appreciate their novelty at the time, if we recall that when similar conclusions were put forward by Helmholtz twenty-three years later, their validity was disputed by so acute a critic as Bertrand. The splendid edifice, concerning the theory of inviscid fluids, which Helmholtz raised upon these foundations, is the admiration of all students of Hydrodynamics.

In applying the above purely kinematical analysis to viscous fluids, Stokes lays down the following principle:—"That the difference between the pressure on a plane passing through any point P of a fluid in motion and the pressure which would exist in all directions about P if the fluid in its neighbourhood were in a state of relative equilibrium depends only on the relative motion of the fluid immediately about P; and that the relative motion due to any motion of rotation may be eliminated without affecting the differences of the pressures above mentioned." This leads him to general dynamical equations, such as had already been obtained by Navier and Poisson, starting from more special hypotheses as to the constitution of matter.

Among the varied examples of the application of the general equations two may be noted. In one of these, relating to the motion of fluid between two coaxial revolving cylinders, an error of Newton's is corrected. In the other, the propagation of sound, as influenced by viscosity, is examined. It is shown that the action of viscosity (μ) is to make the intensity of the sound diminish as the time increases, and to render the velocity of propagation less than it would otherwise be. Both effects are greater for high than for low notes; but the former depends on the first power of μ, while the latter depends only on μ^2, and may usually be neglected.

In the same paragraph there occur two lines in which a question, which has recently been discussed on both sides, and treated as a novelty, is disposed of. The words are—"we may represent an arbitrary disturbance of the medium as the aggregate of series of plane waves propagated in all directions."

In the third section of the memoir under consideration, Stokes applies the same principles to find the equations for an elastic solid. In his view the two elastic constants are independent and not reducible

to one, as in Poisson's theory of the constitution of matter. He refers to indiarubber as hopelessly violating Poisson's condition. Stokes' position, powerfully supported by Lord Kelvin, seems now to be generally accepted. Otherwise, many familiar materials must be excluded from the category of elastic solids.

In 1846 he communicated to the British Association a Report on Recent Researches in Hydrodynamics. This is a model of what such a survey should be, and the suggestions contained in it have inspired many subsequent investigations. He greatly admired the work of Green, and his comparison of opposite styles may often recur to the reader of mathematical lucubrations. Speaking of the Reflection and Refraction of Sound, he remarks that "this problem had been previously considered by Poisson in an elaborate memoir. Poisson treats the subject with extreme generality, and his analysis is consequently very complicated. Mr. Green, on the contrary, restricts himself to the case of plane waves, a case evidently comprising nearly all the phenomena connected with this subject which are of interest in a physical point of view, and thus is enabled to obtain his results by a very simple analysis. Indeed Mr. Green's memoirs are very remarkable, both for the elegance and rigour of the analysis, and for the ease with which he arrives at most important results. This arises in a great measure from his divesting the problems he considers of all unnecessary generality; where generality is really of importance he does not shrink from it. In the present instance there is one important respect in which Mr. Green's investigation is more general than Poisson's, which is, that Mr. Green has taken the case of any two fluids, whereas Poisson considered the case of two elastic fluids, in which equal condensations produce equal increments of pressure. It is curious, that Poisson, forgetting this restriction, applied his formulæ to the case of air and water. Of course his numerical result is quite erroneous. Mr. Green easily arrives at the ordinary laws of reflection and refraction. He obtains also a very simple expression for the intensity of its reflected sound. . . ." As regards Poisson's work in general there was no lack of appreciation. Indeed, both Green and Stokes may be regarded as followers of the French school of mathematicians.

The most cursory notice of Stokes' hydrodynamical researches cannot close without allusion to two important memoirs of somewhat later date. In 1847 he investigated anew the theory of oscillatory waves, as on the surface of the sea, pursuing the approximation so as to cover the case where the height is not very small in comparison with the wave-length. To the reprint in "Math. and Phys. Papers" are added valuable appendices pushing the approximation further by a new method, and showing that the slopes which meet at the crest of

the highest possible wave (capable of propagation without change of type) enclose an angle of 120°.

The other is the great treatise on the Effect of Internal Friction of Fluids on the Motion of Pendulums. Here are given the solutions of difficult mathematical problems relating to the motion of fluid about vibrating solid masses of spherical or cylindrical form; also, as a limiting case, the motion of a viscous fluid in the neighbourhood of a uniformly advancing solid sphere, and a calculation of the *resistance* experienced by the latter. In the application of the results to actual pendulum observations, Stokes very naturally assumed that the viscosity of air was proportional to density. After Maxwell's great discovery that viscosity is independent of density within wide limits, the question assumed a different aspect; and in the reprint of the memoir Stokes explains how it happened that the comparison with theory was not more prejudiced by the use of an erroneous law.

In 1849 appeared another great memoir on the Dynamical Theory of Diffraction, in which the luminiferous æther is treated as an elastic solid so constituted as to behave as if it were nearly or quite incompressible. Many fundamental propositions respecting the vibration of an elastic solid medium are given here for the first time. For example, there is an investigation of the disturbance due to the operation at one point of the medium of a periodic force. The waves emitted are of course symmetrical with respect to the direction of the force as axis. At a distance, the displacement is transverse to the ray and in the plane which includes the axis, while along the axis itself there is no disturbance. Incidentally a general theorem is formulated connecting the disturbances due to initial displacements and velocities. "If any material system in which the forces acting depend only on the positions of the particles be slightly disturbed from a position of equilibrium, and then left to itself, the part of the subsequent motion which depends on the initial displacements may be obtained from the part which depends upon the initial velocities by replacing the arbitrary functions, or arbitrary constants, which express the initial velocities by those which express the corresponding initial displacements, and differentiating with respect to the time."

One of the principal objects of the memoir was to determine the law of vibration of the secondary waves into which in accordance with Huygens' principle a primary wave may be resolved, and thence by a comparison with phenomena observed with gratings to answer a question then much agitated but now (unless restated) almost destitute of meaning, viz., whether the vibrations of light are parallel or perpendicular to the plane of polarisation. As to the law of the secondary wave Stokes' conclusion is expressed in the following theorem: "Let $\xi = 0$, $\eta = 0$, $\zeta = f(bt - x)$ be the displacements

corresponding to the incident light; let O_1 be any point in the plane P, dS an element of that plane adjacent to O_1; and consider the disturbance due to that portion only of the incident disturbance which passes continually across dS. Let O be any point in the medium situated at a distance from the point O_1 which is large in comparison with the length of a wave; let $OO_1 = r$, and let this line make angles θ with the direction of propagation of the incident light, or the axis of x, and ϕ with the direction of vibration, or the axis of z. Then the displacement at O will take place in a direction perpendicular to OO_1, and lying in the plane ZO_1O; and if ζ' be the displacement at O_1 reckoned positive in the direction nearest to that in which the incident vibrations are reckoned positive,

$$\zeta' = \frac{dS}{4\pi r} (1 + \cos\theta) \sin\phi \,.\, f'(bt - r).$$

In particular, if

$$f(bt - x) = c \sin \frac{2\pi}{\lambda} (bt - x),$$

we shall have

$$\zeta' = \frac{c\, dS}{2\lambda r} (1 + \cos\theta) \sin\phi \,.\, \cos \frac{2\pi}{\lambda} (bt - r)."$$

Stokes' own experiments on the polarisation of light diffracted by a grating led him to the conclusion that the vibrations of light are perpendicular to the plane of polarisation.

The law of the secondary wave here deduced is doubtless a possible one, but it seems questionable whether the problem is really so definite as Stokes regarded it. A merely mathematical resolution may be effected in an infinite number of ways; and if the problem is regarded as a physical one, it then becomes a question of the character of the obstruction offered by an actual screen.

As regards the application of the phenomena of diffraction to the question of the direction of vibration, Stokes' criterion finds a better subject in the case of diffraction by very small *particles* disturbing an otherwise uniform medium, as when a fine precipitate of sulphur falls from an aqueous solution.

The work already referred to, as well as his general reputation, naturally marked out Stokes for the Lucasian Professorship, which fell vacant at this time (1849). It is characterised throughout by accuracy of thought and lucidity of statement. Analytical results are fully interpreted, and are applied to questions of physical interest. Arithmetic is never shirked.

Among the papers which at this time flowed plentifully from his pen, one "On Attractions, and on Clairaut's Theorem" deserves special mention. In the writings of earlier authors the law of gravity at the various points of the earth's surface had been deduced from more or

less doubtful hypotheses as the distribution of matter in the interior. It was reserved for Stokes to point out that, in virtue of a simple theorem relating to the potential, the law of gravity follows immediately from the form of the surface, assumed to be one of equilibrium, and that no conclusion can be drawn concerning the internal distribution of attracting matter.

From an early date he had interested himself in Optics, and especially in the Wave Theory. Although, not long before, Herschel had written ambiguously, and Brewster, the greatest living authority, was distinctly hostile, the magnificent achievements of Fresnel had converted the younger generation; and, in his own University, Airy had made important applications of the theory, *e.g.*, to the explanation of the rainbow, and to the diffraction of object-glasses. There is no sign of any reserve in the attitude of Stokes. He threw himself without misgiving into the discussion of outstanding difficulties, such as those connected with the aberration of light, and by further investigations succeeded in bringing new groups of phenomena within the scope of the theory.

An early example of the latter is the paper "On the Theory of certain Bands seen in the Spectrum." These bands, now known after the name of Talbot, are seen when a spectrum is viewed through an aperture half covered by a thin plate of mica or glass. In Talbot's view the bands are produced by the interference of the two beams which traverse the two halves of the aperture, darkness resulting whenever the relative retardation amounts to an odd number of half wave-lengths. This explanation cannot be accepted as it stands, being open to the same objection as Arago's theory of stellar scintillation. A body emitting homogeneous light would not become invisible on merely covering half the aperture of vision with a half wave-plate. That Talbot's view is insufficient is proved by the remarkable observation of Brewster—that the bands are seen only when the retarding plate is held towards the blue side of the spectrum. By Stokes' theory this polarity is fully explained, and the formation of the bands is shown to be connected with the limitation of the aperture, viz., to be akin to the phenomena of diffraction.

A little later we have an application of the general principle of reversion to explain the perfect blackness of the central spot in Newton's rings, which requires that when light passes from a second medium to a first the coefficient of reflection shall be numerically the same as when the propagation is in the opposite sense, but be affected with the reverse sign—the celebrated "loss of half an undulation." The result is obtained by expressing the conditions that the refracted and reflected rays, due to a given incident ray, shall on reversal reproduce that ray and no other.

It may be remarked that on any mechanical theory the reflection from an infinitely thin plate must tend to vanish, and therefore that a contrary conclusion can only mean that the theory has been applied incorrectly.

A not uncommon defect of the eye, known as astigmatism, was first noticed by Airy. It is due to the eye refracting the light with different power in different planes, so that the eye, regarded as an optical instrument, is not symmetrical about its axis. As a consequence, lines drawn upon a plane perpendicular to the line of vision are differently focussed according to their direction in that plane. It may happen, for example, that vertical lines are well seen under conditions where horizontal lines are wholly confused, and *vice versâ*. Airy had shown that the defect could be cured by cylindrical lenses, such as are now common; but no convenient method of testing had been proposed. For this purpose Stokes introduced a pair of plano-cylindrical lenses of equal cylindrical curvatures, one convex and the other concave, and so mounted as to admit of relative rotation. However the components may be situated, the combination is upon the whole neither convex nor concave. If the cylindrical axes are parallel, the one lens is entirely compensated by the other, but as the axes diverge the combination forms an astigmatic lens of gradually increasing power, reaching a maximum when the axes are perpendicular. With the aid of this instrument, an eye, already focussed as well as possible by means (if necessary) of a suitable spherical lens, convex or concave, may be corrected for any degree or direction of astigmatism; and from the positions of the axes of the cylindrical lenses may be calculated, by a simple rule, the curvatures of a single lens which will produce the same result. It is now known that there are comparatively few eyes whose vision may not be more or less improved by an astigmatic lens.

Passing over other investigations of considerable importance in themselves, especially that on the composition and resolution of streams of polarised light from different sources, we come to the great memoir on what is now called Fluorescence, the most far-reaching of Stokes' experimental discoveries. He "was led into the researches detailed in this paper by considering a very singular phenomenon which Sir J. Herschel had discovered in the case of a weak solution of sulphate of quinine and various other salts of the same alkaloid. This fluid appears colourless and transparent, like water, when viewed by transmitted light, but exhibits in certain aspects a peculiar blue colour. Sir J. Herschel found that when the fluid was illuminated by a beam of ordinary daylight, the blue light was produced only throughout a very thin stratum of fluid adjacent to the surface by which the light entered. It was unpolarised. It passed freely through many inches of

the fluid. The incident beam after having passed through the stratum from which the blue light came, was not sensibly enfeebled or coloured, but yet it had lost the power of producing the usual blue colour when admitted into a solution of sulphate of quinine. A beam of light modified in this mysterious manner was called by Sir J. Herschel *epipolised.*

Several years before, Sir D. Brewster had discovered in the case of an alcoholic solution of the green colouring matter of leaves a very remarkable phenomenon, which he has designated as *internal dispersion.* On admitting into this fluid a beam of sunlight condensed by a lens, he was surprised by finding the path of the rays within the fluid marked by a bright light of a blood-red colour, strangely contrasting with the beautiful green of the fluid itself when seen in moderate thickness. Sir David afterwards observed the same phenomenon in various vegetable solutions and essential oils, and in some solids. He conceived it to be due to coloured particles held in suspension. But there was one circumstance attending the phenomenon which seemed very difficult of explanation on such a supposition, namely, that the whole or a great part of the dispersed beam was unpolarised, whereas a beam reflected from suspended particles might be expected to be polarised by reflection. And such was, in fact, the case with those beams which were plainly due to nothing but particles held in suspension. From the general identity of the circumstances attending the two phenomena, Sir D. Brewster was led to conclude that epipolic was merely a particular case of internal dispersion, peculiar only in this respect, that the rays capable of dispersion were dispersed with unusual rapidity. But what rays they were which were capable of affecting a solution of sulphate of quinine, why the active rays were so quickly used up, while the dispersed rays which they produced passed freely through the fluid, why the transmitted light when subjected to prismatic analysis showed no deficiences in those regions to which, with respect to refrangibility, the dispersed rays chiefly belonged, were questions to which the answers appeared to be involved in as much mystery as ever."

Such a situation was well calculated to arouse the curiosity and enthusiasm of a young investigator. A little consideration showed that it was hardly possible to explain the facts without admitting that in undergoing dispersion the light *changed its refrangibility*, but that if this rather startling supposition was allowed, there was no further difficulty; and experiment soon placed the fact of a change of refrangibility beyond doubt. "A pure spectrum from sunlight having been formed in air in the usual manner, a glass vessel containing a weak solution of sulphate of quinine was placed in it. The rays belonging to the greater part of the visible spectrum passed freely through the

fluid, just as if it had been water, being merely reflected here and there from motes. But from a point about halfway between the fixed lines G and H to far beyond the extreme violet, the incident rays gave rise to a light of a sky-blue colour, which emanated in all directions from the portion of the fluid which was under the influence of the incident rays. The anterior surface of the blue space coincided, of course, with the inner surface of the vessel in which the fluid was contained. The posterior surface marked the distance to which the incident rays were able to penetrate before they were absorbed. This distance was at first considerable, greater than the diameter of the vessel, but it decreased with great rapidity as the refrangibility of the incident rays increased, so that from a little beyond the extreme violet to the end, the blue space was reduced to an excessively thin stratum adjacent to the surface by which the incident rays entered. It appears, therefore, that this fluid, which is so transparent with respect to nearly the whole of the visible rays, is of an inky blackness with respect to the invisible rays, more refrangible than the extreme violet. The fixed lines belonging to the violet and the invisible region beyond were beautifully represented by dark planes interrupting the blue space. When the eye was properly placed these planes were, of course, projected into lines."

At a time when photography was of much less convenient application than at present—even wet collodion was then a novelty—the method of investigating the ultra-violet region of the spectrum by means of fluorescence was of great value. The obstacle presented by the imperfect transparency of *glass* soon made itself apparent, and this material was replaced by *quartz* in the lenses and prisms, and in the mirror of the heliostat. When the electric arc was substituted for sunlight a great extension of the spectrum in the direction of shorter waves became manifest.

Among the substances found "active" were the salts of uranium—an observation destined after nearly half a century to become in the hands of Becquerel the starting point of a most interesting scientific advance, of which we can hardly yet foresee the development.

In a great variety of cases the refrangibility of the dispersed light was found to be *less* than that of the incident. That light is always degraded by fluorescence is sometimes referred to as Stokes' law. Its universality has been called in question, and the doubt is perhaps still unresolved. The point is of considerable interest in connection with theories of radiation and the second law of Thermodynamics.

Associated with fluorescence there is frequently seen a "false dispersion," due to suspended particles, sometimes of extreme minuteness. When a horizontal beam of falsely dispersed light was viewed from above in a vertical direction, and analysed, it was found to

consist chiefly of light polarised in the plane of reflection. On this fact Stokes founded an important argument as to the direction of vibration of polarised light. For "if the diameters of the (suspended) particles be small compared with the length of a wave of light, it seems plain that the vibrations in a reflected ray cannot be perpendicular to the vibrations in the incident ray." From this it follows that the direction of vibration must be perpendicular to the plane of polarisation, as Fresnel supposed, and the test seems to be simpler and more direct than the analogous test with light diffracted from a grating. It should not be overlooked that the argument involves the supposition that the effect of a particle is to *load* the æther.

It was about this time that Lord Kelvin learned from Stokes "Solar and Stellar Chemistry." "I used always to show [in lectures at Glasgow] a spirit lamp flame with salt on it, behind a slit prolonging the dark line D by bright continuation. I always gave your dynamical explanation, always asserted that certainly there was sodium vapour in the sun's atmosphere and in the atmospheres of stars which show presence of the D's, and always pointed out that the way to find other substances besides sodium in the sun and stars was to compare bright lines produced by them in artificial flames with dark lines of the spectra of the lights of the distant bodies."*

Stokes always deprecated the ascription to him of much credit in this matter; but what is certain is, that had the scientific world been acquainted with the correspondence of 1854, it could not have greeted the early memoir of Kirchhoff (1859) as a new revelation. This correspondence will appear in Vol. IV of Stokes' Collected Papers, now being prepared under the editorship of Prof. Larmor. The following is from a letter of Kelvin, dated March 9, 1854: "It was Miller's experiment (which you told me about a long time ago) which first convinced me that there must be a physical connection between agency going on in and near the sun, and in the flame of a spirit lamp with salt on it. I never doubted, after I learned Miller's experiment, that there *must* be such a connection, nor can I conceive of any one knowing Miller's experiment and doubting. . . . . . If it could only be made out that the bright line D never occurs without soda, I should consider it perfectly certain that there is soda or sodium in some state in or about the sun. If bright lines in any other flames can be traced, as perfectly as Miller did in his case, to agreement with dark lines in the solar spectrum, the connection would be equally certain, to my mind. I quite expect a qualitative analysis of the sun's atmosphere by experiments like Miller's on other flames."

By temperament, Stokes was over-cautious. "We must not go too fast," he wrote. He felt doubts whether the effects might not be due

* Letter to Stokes, published in Edinburgh address, 1871.

to some constituent of sodium, supposed to be broken up in the electric arc or flame, rather than to sodium itself. But his facts and theories, if insufficient to satisfy himself, were abundantly enough for Kelvin, and would doubtless have convinced others. If Stokes hung back, his correspondent was ready enough to push the application and to formulate the conclusions.

It is difficult to restrain a feeling of regret that these important advances were no further published than in Lord Kelvin's Glasgow lectures. Possibly want of time prevented Stokes from giving his attention to the question. Prof. Larmor significantly remarks that he became Secretary of the Royal Society in 1854. And the reader of the Collected Papers can hardly fail to notice a marked falling off in the speed of production after this time. The reflection suggests itself that scientific men should be kept to scientific work, and should not be tempted to assume heavy administrative duties, at any rate until such time as they have delivered their more important messages to the world.

But if there was less original work, science benefited by the assistance which, in his position as Secretary of the Royal Society, he was ever willing to give to his fellow workers. The pages of the "Proceedings" and "Transactions" abound with grateful recognitions of help thus rendered, and in many cases his suggestions or comments form not the least valuable part of memoirs which appear under the names of others. It is not in human nature for an author to be equally grateful when his mistakes are indicated, but from the point of view of the Society and of science in general, the service may be very great. It is known that in not a few cases the criticism of Stokes was instrumental in suppressing the publication of serious errors.

No one could be more free than he was from anything like an unworthy jealousy of his comrades. Perhaps he would have been the better for a little more wholesome desire for reputation. As happened in the case of Cavendish, too great an indifference in this respect, especially if combined with a morbid dread of mistakes, may easily lead to the withholding of valuable ideas and even to the suppression of elaborate experimental work, which it is often a labour to prepare for publication.

In 1857 he married Miss Robinson, daughter of Dr. Romney Robinson, F.R.S., astronomer of Armagh. Their first residence was in rooms over a nursery gardener's in the Trumpington Road, where they received visits from Whewell and Sedgwick. Afterwards they took Lensfield Cottage, where they resided until her death in 1899. Though of an unusually quiet and silent disposition, he did not like being alone. He was often to be seen at parties and public functions, and, indeed, rarely declined invitations. In later life, after he had

become President of the Royal Society, the hardihood and impunity with which he attended public dinners were matters of general admiration. The nonsense of fools, or rash statements by men of higher calibre, rarely provoked him to speech; but if directly appealed to, he would often explain his view at length with characteristic moderation and lucidity.

His experimental work was executed with the most modest appliances. Many of his discoveries were made in a narrow passage behind the pantry of his house, into the window of which he had a shutter fixed with a slit in it and a bracket on which to place crystals and prisms. It was much the same in lecture. For many years he gave an annual course on Physical Optics, which was pretty generally attended by candidates for mathematical honours. To some of these, at any rate, it was a delight to be taught by a master of his subject, who was able to introduce into his lectures matter fresh from the anvil. The present writer well remembers the experiments on the spectra of blood, communicated in the same year (1864) to the Royal Society. There was no elaborate apparatus of tanks and "spectroscopes." A test-tube contained the liquid and was held at arm's length behind a slit. The prism was a small one of 60°, and was held to the eye without the intervention of lenses. The blood in a fresh condition showed the characteristic double band in the green. On reduction by ferrous salt, the double band gave place to a single one, to re-assert itself after agitation with air. By such simple means was a fundamental reaction established. The impression left upon the hearer was that Stokes felt himself as much at home in chemical and botanical questions as in Mathematics and Physics.

At this time the scientific world expected from him a systematic treatise on Light, and indeed a book was actually advertised as in preparation. Pressure of work, and perhaps a growing habit of procrastination, interfered. Many years later (1884–1887) the Burnett Lectures were published. Simple and accurate, these lectures are a model of what such lectures should be, but they hardly take the place of the treatise hoped for in the sixties. There was, however, a valuable report on Double Refraction, communicated to the British Association in 1862, in which are correlated the work of Cauchy, MacCullagh and Green. To the theory of MacCullagh, Stokes, imbued with the ideas of the elastic solid theory, did less than justice. Following Green, he took too much for granted that the elasticity of æther must have its origin in *deformation*, and was led to pronounce the incompatibility of MacCullagh's theory with the laws of Mechanics. It has recently been shown at length by Prof. Larmor that MacCullagh's equations may be interpreted on the supposition that what is resisted is not deformation, but *rotation*. It is interesting to note that Stokes

here expressed his belief that the true dynamical theory of double refraction was yet to be found.

In 1885 he communicated to the Society his observations upon one of the most curious phenomena in the whole range of Optics—a peculiar internal coloured reflection from certain crystals of chlorate of potash. The seat of the colour was found to be a narrow layer, perhaps one-thousandth of an inch in thickness, apparently constituting a twin stratum. Some of the leading features were described as follows:—

(1) If one of the crystalline plates be turned round in its own plane, without alteration of the angle of incidence, the peculiar reflection vanishes twice in a revolution, viz., when the plane of incidence coincides with the plane of symmetry of the crystal.

(2) As the angle of incidence is increased, the reflected light becomes brighter, and rises in refrangibility.

(3) The colours are not due to absorption, the transmitted light being strictly complementary to the reflected.

(4) The coloured light is not polarised.

(5) The spectrum of the reflected light is frequently found to consist almost entirely of a comparatively narrow band. In many cases the reflection appears to be almost total.

Some of these peculiarities, such, for example, as the evanescence of the reflection at perpendicular incidence, could easily be connected with the properties of a twin plane, but the copiousness of the reflection at moderate angles, as well as the high degree of selection, were highly mysterious. There is reason to think that they depend upon a regular, or nearly regular, alternation of twinning many times repeated.

It is impossible here to give anything more than a rough sketch of Stokes' optical work, and many minor papers must be passed over without even mention. But there are two or three contributions to other subjects as to which a word must be said.

Dating as far back as 1857 there is a short but important discussion on the effect of wind upon the intensity of sound. That sound is usually ill heard up wind is a common observation, but the explanation is less simple than is often supposed. The velocity of moderate winds in comparison with that of sound is too small to be of direct importance. The effect is attributed by Stokes to the fact that winds usually increase overhead, so that the front of a wave proceeding up wind is more retarded above than below. The front is thus tilted; and since a wave is propagated normally to its front, sound proceeding up wind tends to rise, and so to pass over the heads of observers situated at the level of the source, who find themselves, in fact, in a sound shadow.

In a more elaborate memoir (1868) he discusses the important subject of the communication of vibration from a vibrating body to

a surrounding gas. In most cases a solid body vibrates without much change of volume, so that the effect is represented by a distribution of sources over the surface, of which the components are as much negative as positive. The resultant is thus largely a question of *interference*, and it would vanish altogether were it not for the different situations and distances of the positive and negative elements. In any case it depends greatly upon the *wave-length* (in the gas) of the vibration in progress. Stokes calculates in detail the theory for vibrating spheres and cylinders, showing that when the wave-length is large relatively to the dimensions of the vibrating segments, the resultant effect is enormously diminished by interference. Thus the vibrations of a piano-string are communicated to the air scarcely at all directly, but only through the intervention of the sounding board.*

On the foundation of these principles he easily explains a curious observation by Leslie, which had much mystified earlier writers. When a bell is sounded in hydrogen, the intensity is greatly reduced. Not only so, but reduction accompanies the actual addition of hydrogen to rarefied air. The fact is that the hydrogen increases the wave-length, and so renders more complete the interference between the sounds originating in the positively and negatively vibrating segments.

The determination of the laws of viscosity in gases was much advanced by him. Largely through his assistance and advice, the first decisive determinations at ordinary temperatures and pressures were effected by Tomlinson. At a later period he brilliantly took advantage of Crookes' observations on the decrement of oscillation of a vibrator in a partially exhausted space to prove that Maxwell's law holds up to very high exhaustion and to trace the mode of subsequent departure from it. Throughout the course of Crookes' investigations on the electric discharge in vacuum tubes, in which he was keenly interested and closely concerned, he upheld the British view that the cathode stream consists of projected particles which excite phosphorescence in obstacles by impact: and accordingly, after the discovery of the Röntgen rays, he came forward with the view that they consisted of very concentrated spherical pulses travelling through the æther, but distributed quite fortuitously because excited by the random collisions of the cathode particles.

A complete estimate of Stokes' position in scientific history would need a consideration of his more purely mathematical writings, especially of those on Fourier series and the discontinuity of arbitrary constants in semi-convergent expansions over a plane, but this would demand much space and another pen. The present inadequate survey may close with an allusion to another of those "notes," suggested by

* It may be worth notice that similar conclusions are more simply reached by considering the particular case of a *plane* vibrating surface.

the work of others, where Stokes in a few pages illuminated a subject hitherto obscure. By an adaptation of Maxwell's colour diagram he showed (1891) how to represent the results of experiments upon ternary mixtures, with reference to the work of Alder Wright. If three points in the plane represent the pure substances, all associations of them are quantitatively represented by points lying within the triangle so defined. For example, if two points represent water and ether, all points on the intermediate line represent associations of these substances, but only small parts of the line near the two ends correspond to *mixture*. If the proportions be more nearly equal, the association separates into two parts. If a third point (off the line) represents alcohol, which is a solvent for both, the triangle may be divided into two regions, one of which corresponds to single mixtures of the three components, and the other to proportions for which a single mixture is not possible.

A consideration of Stokes' work, even though limited to what has here been touched upon, can lead to no other conclusion than that in many subjects, and especially in Hydrodynamics and Optics, the advances which we owe to him are fundamental. Instinct, amounting to genius, and accuracy of workmanship are everywhere apparent; and in scarcely a single instance can it be said that he has failed to lead in the right direction. But, much as he did, one can hardly repress a feeling that he might have done still more. If the activity in original research of the first fifteen years had been maintained for twenty years longer, much additional harvest might have been gathered in. No doubt distractions of all kinds multiplied, and he was very punctilious in the performance of duties more or less formal. During the sitting of the last Cambridge Commission he interrupted his holiday in Ireland to attend a single meeting, at which however, as was remarked, he scarcely opened his mouth. His many friends and admirers usually took a different view from his of the relative urgency of competing claims. Anything for which a date was not fixed by the nature of the case, stood a poor chance. For example, owing to projected improvements and additions, the third volume of his Collected Works was delayed until eighteen years after the second, and fifty years after the first appearance of any paper it included. Even this measure of promptitude was only achieved under much pressure, private and official.

But his interest in matters scientific never failed. The intelligence of new advances made by others gave him the greatest joy. Notably was this the case in late years with regard to the Röntgen rays. He was delighted at seeing a picture of the arm which he had broken sixty years before, and finding that it showed clearly the united fracture.

Although this is not the place to dilate upon it, no sketch of Stokes can omit to allude to the earnestness of his religious life. In early years he seems to have been oppressed by certain theological difficulties, and was not exactly what was then considered orthodox. Afterwards he saw his way more clearly. In later life he took part in the work of the Victoria Institute: the spirit which actuated him may be judged from the concluding words of an Address on Science and Revelation. "But whether we agree or cannot agree with the conclusions at which a scientific investigator may have arrived, let us, above all things, beware of imputing evil motives to him, of charging him with adopting his conclusions for the purpose of opposing what is revealed. Scientific investigation is eminently truthful. The investigator may be wrong, but it does not follow he is other than truth-loving. If on some subjects which we deem of the highest importance he does not agree with us—and yet he may agree with us more nearly than we suppose—let us, remembering our own imperfections, both of understanding and of practice, bear in mind that caution of the Apostle: 'Who art thou that judgest another man's servant? To his own master he standeth or falleth.'"

Scientific honours were showered upon him. He was Foreign Associate of the French Institute, and Knight of the Prussian Order *Pour le Mérite*. He was awarded the Gauss Medal in 1877, the Arago on the occasion of the Jubilee Celebration in 1899, and the Helmholtz in 1901. In 1889 he was made a Baronet on the recommendation of Lord Salisbury. From 1887 to 1891 he represented the University of Cambridge in Parliament, in this, as in the Presidency of the Society, following the example of his illustrious predecessor in the Lucasian Chair. He was Secretary of the Society from 1854 to 1885, President from 1885 to 1890, received the Rumford medal in 1852, and the Copley in 1893.

But the most remarkable testimony by far to the estimation in which he was held by his scientific contemporaries was the gathering at Cambridge in 1899, in celebration of the Jubilee of his Professorship. Men of renown flocked from all parts of the world to do him homage, and were as much struck by the modesty and simplicity of his demeanour as they had previously been by the brilliancy of his scientific achievements. The beautiful lines by his colleague, Sir R. Jebb, cited below, were written upon this occasion.

There is little more to tell. In 1902 he was chosen Master of Pembroke. But he did not long survive. At the annual dinner of the Cambridge Philosophical Society, held in the College about a month before his death, he managed to attend though very ill, and made an admirable speech, recalling with charming simplicity and courtesy his lifelong intimate connection with the College, to the

Mastership of which he had recently been called, and with the Society through which he had published much of his scientific work. Near the end, while conscious that he had not long to live, he retained his faculties unimpaired; only during the last few hours he wandered slightly, and imagined that he was addressing the undergraduates of his College, exhorting them to purity of life. He died on the first of February, 1903.

Clear mind, strong heart, true servant of the light,
True to that light within the soul, whose ray
Pure and serene, hath brightened on thy way,
Honour and praise now crown thee on the height
Of tranquil years. Forgetfulness and night
Shall spare thy fame, when in some larger day
Of knowledge yet undream'd, Time makes a prey
Of many a deed and name that once were bright.

Thou, without haste or pause, from youth to age,
Hast moved with sure steps to thy goal. And thine
That sure renown which sage confirms to sage,
Borne from afar. Yet wisdom shows a sign
Greater, through all thy life, than glory's wage;
Thy strength hath rested on the Love Divine.

R.

LORD ARMSTRONG. 1810—1900.

Lord Armstrong, F.R.S., died December 27, 1900, at the venerable age of 90. The preparation of this brief memoir, by one who was for many years closely associated with him, has been delayed by unavoidable causes. A full biography of him has yet to be published: within the scope of an article like this it is impossible to do more than enumerate the principal episodes in the career of one whose days were so many, whose interests were so various, and the sum of whose achievements was so considerable.

William George Armstrong was born in Pleasant Row, Shieldfield, Newcastle-upon-Tyne, on November 26, 1810. His father belonged to Cumberland, and migrated to Newcastle at the end of the eighteenth century. He must have been a man of character and ability, for he came to the town as a clerk in a corn merchant's office, and from this small beginning rose to commercial independence and municipal importance. After serving for many years as a member of the Town Council he was elected Mayor in 1850. He was also, and the fact is of interest in connection with his son's reputation, equipped with a taste for learning, and was especially fond of mathematics. He helped to found the Literary and Philosophical Society of Newcastle-upon-Tyne, and joined in some mathematical discussions, of which a curious old manuscript record is still extant. Among these transactions is to be found a passage where Mr. Armstrong is assailed by a Mr. Howard, with an amazing wealth of invective, upon a question so wanting in excitement to most as the value in algebra and geometry of imaginary quantities. He married Miss Potter, of Walbottle Hall, and two children were born to him, a daughter, who became, in 1826, the wife of William Watson, afterwards a Baron of the Exchequer, and a son, the subject of the present sketch. Mr. Armstrong lived to the age of 80, and died in 1857, by which date the renown of his son was established.

The future engineer, who in early life was a delicate child, was sent in 1826 to the Grammar School at Bishop Auckland, where he boarded with the Rev. R. Thompson. Anecdotes of his boyhood are rare, and possibly apocryphal. He seems soon to have displayed a fondness for mechanical toys, and a curiosity as to the manner in which such toys worked, but there is not much evidence that he showed these characteristics in a more marked degree than many boys before and since. However as he grew older his bent towards mechanics became more

pronounced, and when, after his school career, he entered a solicitor's office, he continued his scientific studies in the leisure time at his disposal.

There is no necessity for presuming that young Armstrong was forced into an uncongenial path of life. Mr. Armourer Donkin, to whom he was articled, was a well-known Newcastle solicitor with a good business, and had always shown himself a firm friend of the Armstrong family. The opening which Mr. Donkin's office promised was an exceptional one, and led, in fact, to Lord Armstrong becoming a partner in the firm in 1833. No doubt he acquiesced readily in a scheme which assured him an income, and as events turned out the arrangement really laid the foundations of his future success. Ample leisure was allowed him to devote himself to pursuits outside his profession, and the alliance and support of Mr. Donkin proved of the utmost value to him. When he finally relinquished the law and opened his engineering works, Mr. Donkin contributed a share of the necessary capital, and supported his enterprise in every possible way.

A stray book, exhumed among some papers at Elswick, contains copies of letters written by Lord Armstrong in the years 1837 and 1838. The correspondence is both upon official and personal subjects, ranging from formal missives, signed "Donkin, Stables and Armstrong," to an order upon Mr. James Poole for a coat, suitable for the general mourning at the death of King William IV. There are not many letters, but the impression given is that the writer was transacting a large amount of business for various clients, and transacting it with pains and diligence. Lord Armstrong, there can be no question, must have made an excellent lawyer, even although his heart may not have been entirely in his calling. For he had the mind of an extremely lucid thinker, and a real taste for disentangling intricate questions. One of the letters in the book mentioned above, in treating at some length of a financial matter, handles it with conspicuous clearness, and shows a thorough grasp of the subject.

Lord Armstrong married in 1835 Margaret Ramshaw, the daughter of a Bishop Auckland gentleman, whose acquaintance he had made during his school days. Remembering the position to which the young solicitor afterwards attained, it is curious to notice that his choice of a wife was considered a little ambitious. Lady Armstrong was a woman of strong individuality, and loyally supported her husband in all his undertakings. She was much interested in and liked by the workpeople at Elswick and the villagers at Rothbury, identifying herself with their affairs in a spirit of genuine philanthropy. She died in the autumn of 1893.

The first scientific discovery which brought the name of Armstrong before the public was his hydro-electric machine, and it is curious that

his earliest and latest researches lay in the direction of electrical science. Attention had been turned to the statements of workmen at Cramlington Collieries that, in attempting to adjust the safety valve while steam was blowing off, they had experienced severe electric shocks. Lord Armstrong, among others, was interested by this phenomenon, and communicated his experiments in connection with it to the "Philosophical Magazine" in 1840 and 1841. He continued to experiment with the indefatigable perseverance which always distinguished his researches, and it was not until 1844 that he ventured to exhibit the results in public. In that year he brought before the Literary and Philosophical Society of Newcastle-upon-Tyne a hydro-electric machine, constructed to his design by Messrs. Watson and Lambert. Several of these machines were ordered by scientific institutions upon the Continent, and one was exhibited by Prof. Faraday at the Polytechnic. In this apparatus, steam was made to issue through wooden nozzles, perforated with a crooked passage in order to increase the friction. The collector consisted of a row of spikes placed in the path of the steam jets issuing from the nozzles, and was supported, together with a brass ball which served as a prime conductor, upon a glass pillar. It was the most powerful machine known at the time for producing electricity of high tension, and yielded sparks five or six feet long.

Almost immediately afterwards Lord Armstrong was elected a Fellow of the Royal Society. He was described in his certificate as a solicitor of Newcastle-upon-Tyne, "a gentleman well known as an earnest investigator of physical science, especially with reference to the electricity of steam, and the inventor of the hydro-electric machine." Among the signatures to this certificate were those of Buckland, Faraday, Owen, Grove, and Wheatstone. It is dated March 10, 1846, and Lord Armstrong was elected on May 7, 1846. In those days there was no fixed date for the annual election, nor was there apparently any limit to the number of new Fellows who might be admitted each year. There was about this time some dissatisfaction among the Fellows with the condition of the Society, and, as a result the statutes were revised in 1847. Since that date only fifteen new elections have been made annually. In the year 1846, when Lord Armstrong was elected, he was one of twenty-five successful candidates. Among the more interesting names in the list are those of Major Cautley, the constructor of the Ganges Canal, Wilberforce, Bishop of Oxford, and James Neilson, the inventor of the hot blast for blast furnaces. When Lord Armstrong died in 1900 he was in point of election the third oldest Fellow, senior to him being General Riddell and Sir John Simon, and in point of years the oldest but one, Dr. Glaisher, who was born in 1809. Lord Armstrong served upon the Council of the Society in 1861 and 1862.

Long before his invention of the hydro-electric machine Lord Armstrong had been engaged upon another investigation, which was destined to produce more important results. As far back as 1835 he had begun to consider the subject of water pressure and the manner in which that pressure might be adapted to machinery. He made no secret of his ideas, but communicated them to the "Mechanic's Magazine," in 1838, though without arousing any public interest in the subject. His association with the Newcastle Water Company—a company which was due to his initiation, and which to this day supplies Newcastle with water—gave him further opportunities of testing his theories, and at length, after nearly ten years of experiment, his first hydraulic machine was produced. This machine is still to be seen at Elswick. It is a species of rotary engine, admitting of a continuous and uniform flow of water through it, and exempt from all contracted passages. Tried in Newcastle with a pressure from the street pipes equivalent to a column of water of about 200 feet, it yielded a very high effect. It is needless to say that this early form was soon superseded. Whittledene reservoir, 400 feet above high-water mark, suggested to him the possibility of using this source of power, and by permission of the Newcastle Town Council he erected, at his own expense, the first hydraulic crane, which proved a great success, and soon attracted the attention of engineers.

One of the first to inspect the crane was Mr. Hartley, the chief engineer of the Liverpool Docks, who was very sceptical as to the success of the new crane. He was, when enquiring into facts he considered doubtful, exceedingly rough in his manner, and was so with the man in charge, who was known by the name of "Hydraulic Jack," and who had become exceedingly skilful in his management of the crane. Hydraulic Jack asked Mr. Hartley what he would give him if he let his load drop and picked it up again. A reward was promised if successful, and the load was allowed to drop at a great speed, was as suddenly stopped, and raised again smoothly and rapidly to its original position. Mr. Hartley declared the crane to be exactly what he wanted, and gave an order for the Liverpool Docks, the forerunner of the very considerable work done by Elswick for Liverpool and Birkenhead.

The success of this crane created so considerable a demand for cranes and other hydraulic machinery that Lord Armstrong in 1847 ceased to practice as a solicitor, and also resigned the Secretaryship of the Water Company, and devoted the whole of his time and attention to starting the Elswick Engine Works.

Lord Armstrong's early partners at Elswick were Mr. Donkin, Mr. Addison Potter, Mr. George Cruddas, and Mr. R. Lambert, and the support they gave to, and the trust they reposed in the genius of their partner, inventor, and manager never faltered in spite of the

many difficulties necessarily met with in works newly started and engaged in a novel manufacture. With the single exception of Mr. Cruddas, whose son is a director of the present company, the names of Lord Armstrong's early friends and partners have long since disappeared from the firm.

The early cranes and other hydraulic machinery were at first worked by water from a natural head, but, as the demand for hydraulic machinery increased, the Elswick Works were asked to supply cranes, etc., for situations where sufficient natural pressure was not obtainable. This led Lord Armstrong to devise his accumulator, consisting of a cylinder, of dimensions varying with the amount of work required to be done, into which was pumped water, raising a load usually adjusted to give to the water in the cylinder and pipes a pressure of from 700 to 800 lbs. on the square inch. This invention had the advantage of allowing the system to be employed in any situation, and had also the advantage of being nearly free from the fluctuations of pressure so common in water pipes. Much smaller pipes also could be employed.

It would be out of place here to describe the innumerable applications of water power which have resulted from Lord Armstrong's labours. Hydraulic power has been found especially useful, where power is required intermittently and for short periods of time, and further has the advantage of transmitting, with little loss, power to considerable distances.

Elswick was busy with hydraulic work when its founder entered upon a new field. The Battle of Inkerman was fought on November 5, 1854. The result of the day was greatly influenced by the action of Colonel, now General, Sir Collingwood Dickson, V.C., G.C.B., who by incredible exertion dragged two 18-pounders up a hill where their superior range and power proved of great value. The incident attracted Lord Armstrong's attention, and led him to consider whether these heavy and clumsy pieces could not be replaced by guns much lighter, but with equal or greater power and equal or greater range. In December, 1854, he had an interview with the Duke of Newcastle, the first Secretary of State for War, who authorised him to submit for trial guns of different calibres, but not exceeding six in number.

The first gun on his system submitted was a 3-pounder, weighing 5 cwts., and was a breechloader rifled on the polygroove system. The breech action consisted of a movable vent-piece, which dropped into a slot in the gun and was screwed firmly into place. Obturation was secured pretty effectively by copper rings in the front of the vent-piece and in the barrel. The very early small guns had steel barrels reinforced with coiled iron hoops, a construction which was adopted shortly afterwards and for a very considerable time remained that of the Service.

The Ordnance Committee in the first instance received the gun with a discouraging lack of enthusiasm. It was objected that it could fire neither common or shrapnel shell, and the inventor, feeling the force of this objection, re-bored the gun so as to make it a 5-pounder, and substituted for the lead shot a cast-iron shell, for which he devised time, concussion, and direct-action fuzes. The official wheels moved slowly, but in January, 1857, a further step was taken, and Lord Armstrong was authorised to supply a gun upon his system, to correspond in weight with the Service 9-pounder gun of $13\frac{1}{2}$-cwt. Within the prescribed weight he submitted an 18-pounder gun, which, tried in competition with the Service guns at Shoeburyness, utterly defeated them in every detail.

This gun was submitted in July, 1857, and in February, 1858, the Superintendent of Experiments reported "that the very extraordinary powers of range and precision of fire exhibited at Shoeburyness from the breechloading gun of Mr. Armstrong's invention appear to afford a reasonable expectation that artillery will not only regain that influence in the field, of which to a certain extent it has been deprived by the recent introduction of rifled small arms, but that influence will be most materially increased."

Lord Panmure, who was then Secretary of State for War, expressed himself equally strongly. In August, 1858, a Special Committee on rifled cannon was appointed, which examined and reported on rifled guns submitted by seven different inventors. In their report to the War Office, they divided the guns submitted to them into two classes. The first class included the guns of Mr. Armstrong and Mr. Whitworth. As regards the second class, they recommended that no further expense should be incurred with respect to them.

They unanimously recommended that the Armstrong gun should be introduced into the Service, both on account of its accuracy, the perfection of its workmanship, and the completeness with which the projectiles, fuzes, and other details had been worked out. Some idea of the advance in accuracy by the introduction of rifled guns may be gathered from an appendix attached to the Committee's Report, by which it appears that at 1,000 yards range half of the shot fired from the smooth-bored field gun of the Service fell in a rectangle 92 yards long by 7 yards wide, while the corresponding rectangle with the Armstrong gun was 17 yards long by 0·8 yards wide.

On the adoption of his gun Lord Armstrong placed his inventions at the disposal of the nation, severed for a time his connection with his firm, and received the honours of knighthood and the Companionship of the Bath. He was then appointed Engineer of Rifled Ordnance and Superintendent of the Royal Gun Factories; an arrangement was made with the newly-formed Elswick Ordnance Company, and the

manufacture of the new rifled guns was carried on both at Woolwich and at Elswick. This arrangement was continued until the agreement with the Elswick Company was put an end to, when, at the request of his old partners, he resigned his Government appointment and rejoined the firm. It is unnecessary here to do more than allude to the "Armstrong and Whitworth Committee," and the artillery questions which for so many years vexed experts, but it is interesting to remember that the Armstrong and Whitworth firms amalgamated in 1897 and now combine in one company the names of their great founders. It is more important to note the retrograde step which at this time was taken by the British Government. The high naval and military officers of the day considered simplicity to be all important, and there was great difficulty in introducing even the most simple mechanical contrivance. Some defects, which might easily have been remedied, were found in parts of the breech mechanism, if careful attention were not given when closing, and it was decided to revert to muzzle loading. That determination placed this country at a serious disadvantage, and does not appear to have been reconsidered until, in 1878, the Elswick firm, guided by their recent researches in explosives, submitted to the Government 6-inch and 8-inch guns, both breech and muzzle loading, with which velocities of over 2,100 f.s. were obtained. The highest velocities of the then Service muzzle-loaders did not reach 1,600 f.s., and the difference in energy due to the above velocities was equivalent to an increase of more than 60 per cent. But to obtain this increase with moderate pressures it was necessary to add largely to the length of the gun, and it soon became obvious that in order to realise the highest energy and efficiency a return to breech loading was a necessity.

Lord Armstrong, whose early guns were all breech loaders, and who, although Elswick made many muzzle loaders, was throughout his career a strong advocate of breech loading, played an important part in this matter. His high authority, and the results shown to be possible, had great weight with the naval and military authorities in regard to the abandonment of the now obsolete muzzle loaders.

Although the subject lies in some degree apart from his scientific career, no record of Lord Armstrong's life would be complete without a passing reference to the future history of the works which he founded. It is common knowledge that in the fifty years which have passed since the period of which we are now treating, Elswick has increased and advanced, until at the present moment it is one of the largest industrial concerns of the world. At the start it owed everything to Lord Armstrong, for not only was he indefatigable himself, but he also made a judicious selection of assistants. He had a born leader's eye for capable men, and rarely made a mistake in his estimate of ability, nor did he hesitate to delegate full responsibility to those who worked with him.

With his retirement in 1863 from a position which had become untenable the public career of Lord Armstrong may be said, in a certain sense, to have come to an end. He was now fifty-three years old: for five years the force of circumstances had placed him in the most commanding position which an inventor has ever occupied. He had revolutionised artillery, and had been the centre of much bitter controversy and argument. He now retired into private life, and took his place again as head of the Elswick Works. The agreement with Government being at an end, there was nothing to prevent the amalgamation of the Engineering and Ordnance Works into one concern. This was at once effected, and a considerable foreign connection, which rapidly increased, spread the fame of the Armstrong guns over the world. About 1870 the building of warships was added to the other operations of Lord Armstrong's firm, and in 1882, an amalgamation with the shipyard of the late Mr. Charles Mitchell took place, and the business was converted into a limited Company. The coalition with Mr. Vavasseur added great strength to the new Company, and later still, as we have already noticed, in 1897, the works of Sir Joseph Whitworth, once the most active rival of Lord Armstrong, were also absorbed, and the Company is now known as Sir W. G. Armstrong, Whitworth & Company, Limited. The subject of Elswick may be dismissed with the remark that it is one of the largest industrial concerns in the world, employing at present 25,000 men, and paying more than £30,000 a week in wages. Such has been the subsequent history of the engineering works founded by Lord Armstrong in 1847. He presided over Elswick, as Chairman of the Company, until the day of his death, and up to the autumn of 1897 took a prominent share in the policy if not in the actual management of the business.

To revert to more personal matters, in 1863 Lord Armstrong was President of the British Association, which held its meeting at Newcastle, and in his presidential address, dealt with the coal supply of the British Islands. His remarks upon this subject aroused considerable interest, and led to the appointment of a Royal Commission, under the chairmanship of the Duke of Argyll, to enquire into the question. Lord Armstrong was a member of this Commission.

Lord Armstrong was also upon more than one occasion associated with the Ordnance Committee in certain special enquiries about artillery. He was always accepted, as he deserved to be, as one of the first authorities upon guns and mountings. After the conversion of his business into a limited Company in 1882, he took the chair annually at the shareholders' meetings, and the addresses which he delivered show the closeness with which he followed the progress made in the construction of war material. It will be remembered no doubt that he especially insisted from time to time on the necessity of fast protected cruisers for the protection of British commerce.

In 1886 he essayed another phase of public life, and came forward as a candidate for Parliament at the General Election. In company with the present Lord Ridley he stood as a Liberal Unionist for his native town. Of that town he had been unquestionably a distinguished benefactor, for, apart from the prosperity which his works had brought to the neighbourhood, he had made many gifts of parks and open spaces to the citizens. Lord Armstrong entered into the campaign with zest, when once he had made up his mind to stand, but the election resulted in the return of the two Gladstonians by a considerable majority. It was generally thought that his position as a large employer of labour militated against the chances of Lord Armstrong in a constituency where the Trade Union vote was so considerable; but even taking this into consideration, the election is still memorable for its surprising issue. In the following year Lord Armstrong was raised to the peerage, his name appearing among the Jubilee honours.

The chief scientific studies of the last years of his life were in the subject of electricity. He lectured in the spring of 1893 to the Literary and Philosophical Society of Newcastle on "Some Features of the Electrical Discharge," and was heard by a crowded audience with the most profound attention. He reminded his hearers how, forty-nine years earlier, in 1844, he had exhibited his hydro-electric machine to the same Society, and how the connection of himself and his father with the Society extended over a century. In 1897 he published some of his later electrical researches in book form.

Lord Armstrong was three times President of the Institute of Mechanical Engineers, and once of the Civil Engineers. He read papers to the British Association, in 1845, upon his hydro-electric machine; in 1854, on the application of water pressure to machinery; and in 1882, on the treatment of steel for ordnance and other purposes. He was a clear and interesting lecturer, though he had no gift for extempore speaking. He took a considerable share in the public life of Northumberland, acting as High Sheriff in 1873, and serving for some time as County Councillor for the Rothbury Division, but he declined to be nominated for the Mayoralty of Newcastle. To all good causes in the North he lent his support, and few charities, public or private, appealed to his purse in vain. His attitude towards the great wealth which his talents won for him was such as might be expected from so large-minded a man. He gave away, as has been mentioned, with consistent munificence and entertained with liberal hospitality. Among the most valuable of his donations in the cause of charity was the munificent contribution of £6,500 (afterwards increased to £7,800), to the subscription started in 1885 for the increment of the Scientific Relief Fund of the Royal Society, a fund established in 1859 to benefit scientific men or their families requiring assistance. This excellent organisation,

which always had the warm sympathy and support of Lord Armstrong, renders assistance in a private and unostentatious way to a class who, from the nature of their position, would not be reached by the more public agencies for the relief of those in embarrassed circumstances.

Nearly forty years ago he determined to build a country house and make an estate worthy of his position. The manner in which he attacked this enterprise is, in its own line, almost as astonishing as anything he ever did. He selected the village of Rothbury as his residence. He had always expressed an affection for this small village among the Northumbrian moors, and used to say that it was the bracing air of Rothbury which turned him from a delicate child into a vigorous man. Here, about the year 1863, he bought an estate, and built a house, which he called "Cragside." This done, he set about transforming the surroundings at vast expense and labour. He reclaimed the waste places, he laid out large gardens; he planted millions of trees; he made roads and lakes. No geographical difficulty was allowed to daunt him, and the result had been a complete transformation of the landscape. Opinions may be divided as to whether so much planting has been an improvement, but, as a monument of big ideas, worked out with consummate energy, the house and estate of Cragside have an unique interest of their own. Much later in his life, in 1894, Lord Armstrong began another building scheme of almost equal magnitude. This was nothing less than the restoration upon the old lines of the ancient castle of Bamburgh. Though he did not live to see this work finished, he was able to go to Bamburgh a few months before his death and inspect the progress of the building.

Lord Armstrong, though he had long retired from active business, maintained his health and his vigour until 1897. In the August of that year, on the occasion of the visit of the King of Siam to Elswick, he was taken ill, it was thought from the effects of some kind of sunstroke. Henceforth he was an invalid, confined to his room, and only occasionally going out for a short drive about his grounds at Cragside. From time to time his health showed improvement, and his understanding remained as clear as ever, but his nerve seemed to be gone, and the smallest exertion fatigued him. In December, 1900, some trivial affection, which his enfeebled frame could not throw off, overtook him, and he died peacefully upon the 27th of December. He was buried on the last day of the nineteenth century in Rothbury Churchyard.

Though Lord Armstrong died recently, the chief achievements of his life were carried out so long ago that it is quite possible to estimate the value of his work. It may be said of him that he was one of a small band of inventors to whom it has been given to profoundly modify the conditions of human life. As the pioneer of hydraulic machinery and engineering he takes a foremost place among the men of

genius who contributed to the material progress of the nineteenth century. There have been many thinkers more strictly scientific, for he was not deeply versed in any special branch of learning. His strength lay rather in the unrivalled activity of his intellect, the quickness of his perception, and the penetrating skill with which he reduced theory to practice. His discoveries and inventions proceeded upon invariable lines: close observation, ingenious deduction, followed by assiduous experiment. His industry in research upon any subject which interested him amounted to a complete absorption for the time being. During his early studies in artillery he would be up day after day at sunrise to fire his gun on the moors or on the seashore. He thought of nothing else, but concentrated the whole force of his mind upon his investigations, to the exclusion of everything else. His talents were rigidly limited to practical issues. It would be an overstatement to describe him as lacking in imagination, but he had no taste whatever for transcendental or speculative enquiries. And, solid as were his theories, his work, whether he was building an engine or a house, was more thorough still. It wanted no detail which industry or perseverance could give it.

In private life Lord Armstrong was the most charming of companions. In the prime of life he was an excellent walker, and was fond of fishing and shooting. He was an excellent host, and in congenial society a striking conversationalist. No man could have lived a simpler life, or borne his honours with less ostentation. Strangers sometimes found his manners rather cold and reserved, and he had a somewhat keen eye for the pretentious, together with a distaste for it which he did not always take the trouble to conceal. Yet nobody had a more generous appreciation of real ability and worth.

In addition to being a Companion of the Bath, Lord Armstrong held the Order of St. Maurice and St. Lazarus of Italy, of the Dannebrog of Denmark, of Jesus Christ of Portugal, of Francis Joseph of Austria, of Charles the Third of Spain, of the Rose of Brazil, of the Dragon of China, and of the Sacred Treasure of Japan. He received the honorary degrees of D.C.L. from Oxford and Durham and of LL.D. from Cambridge.

A. N.

SIR JOHN BENNET LAWES, Bart. 1814—1900.

The manor-house of Rothamsted, situated in the parish of Harpenden, Herts, was the birthplace of John Bennet Lawes, and the Rothamsted farm became, in subsequent years, the scene of the great work of his long life. So far-reaching have been the results which he achieved, that the name of Rothamsted is now a household word wherever the science of Agriculture is studied.

The ancestors of Sir John Lawes had occupied Rothamsted for many generations. Jaques Wittewronge came to England from Flanders in 1564, owing to the religious persecution then prevailing. The manor of Rothamsted was purchased in 1623 for his grandson, John Wittewronge, who was then a minor. John Wittewronge was knighted by Charles I., and afterwards created a baronet by Charles II. In consequence of the failure of male heirs, the manor passed to the Bennet family by the marriage of Elizabeth Wittewronge with Thomas Bennet, and finally to the Lawes family by the marriage of Mary Bennet (great-granddaughter of James Wittewronge) with Thomas Lawes. His son, John Bennet Lawes, was the father of the John Bennet Lawes of whom we have to speak, who was born at Rothamsted on December 28, 1814.

John Bennet Lawes was an only son. He lost his father when eight years old, and owed much to his mother's bringing up. He seems to have led the life of a country boy, and his studies he afterwards described as being "of a most desultory character." Experiments in chemistry, made at home, seem to have been one of his favourite occupations. He was sent successively to Eton, and to Brasenose College, Oxford, which he entered in 1832. While at Oxford he attended some of the lectures of Dr. Daubeny, the professor of chemistry. He left the University without taking a degree.

In 1834 Mr. Lawes entered on the personal management of the home farm at Rothamsted, then of about 250 acres; he at the same time threw himself heartily into chemical investigations. He tells us: "At the age of twenty I gave an order to a London firm to fit up a complete laboratory, and I am afraid it sadly disturbed the peace of mind of my mother to see one of the best bedrooms in the house fitted up with stoves, retorts, and all the apparatus and reagents necessary for chemical research. At the time my attention was very much directed to the composition of drugs; I almost knew the Pharmacopœia by heart, and I was not satisfied until I had made the acquaintance of the author, Dr. A. T. Thomson. The active principle of a

number of substances was being discovered at this time, and, in order to make these substances, I sowed on my farm poppies, hemlock, henbane, colchicum, belladonna, etc. Some of these are still growing about the place. Dr. Thomson had suggested a process for making calomel and corrosive sublimate by burning quicksilver in chlorine gas. I undertook to carry out the process on a large scale, and wasted a good deal of time and money on a process which was, in fact, no improvement on the process then in use."* At this time Dr. Anthony Todd Thomson, Professor of Materia Medica at University College, London, was his chief instructor and adviser. An old barn at Rothamsted was transformed into a laboratory, and here the calomel was afterwards made; this laboratory remained in active use till 1855.

The researches of De Saussure, on the nutrition of plants, seem to have first called Mr. Lawes' attention to the relations between chemistry and agriculture. In 1837 he commenced experiments in pots with agricultural plants, the manures made use of supplying various elements of plant food. These experiments were continued on a larger scale in 1838 and 1839. Spent animal charcoal was then a waste product, and Mr. Lawes was asked by a London friend if it could be turned to any use. He therefore employed it as a manure in his pot experiments, and discovered that if previously treated with sulphuric acid its efficacy as a manure was greatly increased. Apatite and other mineral phosphates were soon treated in a similar manner, and the "superphosphate of lime," thus prepared, was found to be most effective as a manure, especially for turnips. The new superphosphate was employed on a large scale for crops on the Rothamsted farm in 1840 and 1841, and the results were so satisfactory that in 1842 Mr. Lawes took out a patent for the manufacture of superphosphate.

The application of sulphuric acid to bones had been practised before the date of Mr. Lawes' patent; the novelty of his patented invention consisted in the treatment of mineral phosphates in this manner. The supply of bone available for farmers is but small, but the supply of apatite, coprolite, and of the various rock phosphates discovered in recent years, is almost unlimited. These mineral phosphates are usually too insoluble to have any practical value as manure, but by treatment with a limited quantity of sulphuric acid, a mixture of monocalcic phosphate, phosphoric acid, and gypsum is produced. The phosphates in this compound are almost entirely soluble in water, and far more efficacious as manure than the phosphates of raw bone. The enormous influence which the introduction of superphosphate has had on the development of agriculture may be gathered from the quantity now annually employed by farmers. The annual manufacture of

* "Agricultural Gazette," January 2, 1888.

superphosphate in Great Britain amounts at present to about 1,000,000 tons, while the total manufacture in the world is about six times this amount. If Sir John Lawes had done nothing more than introduce the manufacture of artificial manures, he would still rank among the greatest benefactors to agriculture.

The life of Sir John Lawes divides at this point into two parts. He became from the date of his patent a chemical manufacturer, carrying on an extensive London business, and as prosperity increased he embarked in a variety of enterprises. While, however, obliged to spend two days of every week in London, his devotion to agricultural research continued to increase, and the profits yielded by commerce were employed for the creation and maintenance of a large experiment station at Rothamsted. The experiments in the fields had already, at the date of his patent, reached a stage at which the continuous services of a trained chemist were urgently needed. On the recommendation of Dr. A. T. Thomson, Mr. Lawes engaged a young chemist who had studied under Liebig—Dr. J. H. Gilbert. Dr. Gilbert entered upon his work at Rothamsted in June, 1843, and continued actively occupied in the scientific superintendence of the agricultural experiments during the whole of his long life. For fifty-seven years Lawes and Gilbert worked together on a great variety of agricultural problems; of these labours and their results we shall give a brief account after completing our sketch of the life of each worker.

Mr. Lawes married, in 1842, Caroline Fountaine, daughter of Andrew Fountaine, Esq., of Narford Hall, Norfolk. He enjoyed her society for more than fifty years, and her artistic power was not unfrequently employed in providing illustrations of the investigations in progress. As the commencement of manufacturing operations made great demands on his capital, Mr. Lawes at this period let Rothamsted House, and for some years resided either in London or Devonshire.

His first factory for the manufacture of superphosphate was erected at Deptford Creek in 1843. The business rapidly extended, and in 1857 about 100 acres of land were purchased at Barking Creek, and a larger factory erected, including an extensive plant for the manufacture of sulphuric acid. In 1866 Mr. Lawes purchased the tartaric and citric acid factory at Millwall. The purchase was unwillingly made, but the new work was taken up with his accustomed energy and enterprise, many economies and improvements were introduced, and the factory became the most important of its kind in this country. In 1872 he sold the whole of his manure business for £300,000; he retained the tartaric and citric acid factory till his death. Mr. Lawes had also a large sugar estate in Queensland: the low price of sugar and the lack of cheap labour prevented, in this instance, a commercial success.

The investigations at Rothamsted made rapid progress. In 1843

were commenced the systematic field experiments on turnips and wheat; the wheat field has grown wheat without intermission ever since. In 1847 the field experiments on beans commenced, and in 1848 those on clover, and on a four-course rotation. In 1851 the rotations of wheat and fallow, and wheat and beans were started. In 1852 the field experiments on barley commenced. In 1856 those on grass land. In all about 40 acres were brought under experiment. Of all these crops complete chemical statistics were obtained. Experiments on sheep-feeding with various foods commenced in 1848. The whole bodies of ten animals—oxen, sheep, and pigs—of various ages and conditions as to fatness, were analysed between 1848 and 1850. In 1850 an extensive series of pig-feeding experiments was made.

The extent of the work undertaken, its thoroughness, and the practical value of the results obtained, gained the admiration of both scientific and practical men. At a meeting of Hertfordshire farmers at St. Albans, on December 24, 1853, it was resolved to present Mr. Lawes with a testimonial. The circular issued states: "It was considered that Mr. Lawes has for many years been engaged in a series of scientific and disinterested investigations for the improvement of agriculture generally, which have been carried out to an extent, with an attention to accuracy and detail, and at a cost, never before undertaken by any individual, or even by any public institution." The proposal was soon enlarged, and became national in its character. The subscriptions received amounted to about £1,160. At Mr. Lawes' desire, the greater part of this sum was spent in the erection of a new laboratory, which was opened at a gathering of distinguished agriculturists on July 19, 1855, the Earl of Chichester presiding on the occasion. The speeches made by Mr. Lawes, Dr. Gilbert, and others, have fortunately been preserved.* Mr. Lawes, on this occasion, paid a warm tribute to the work done by Dr. Gilbert. Besides the gift of the laboratory, Mr. Lawes received a handsome silver candelabrum, bearing a suitable inscription. In later years the laboratory was found too small for the preparation and storage of the numerous samples, and additional buildings were erected.

Mr. Lawes was elected a Fellow of the Royal Society in 1854, and in 1867 one of the Royal medals was awarded to him and Dr. Gilbert for their systematic researches upon agricultural chemistry. Seven papers by Lawes and Gilbert have been published in the Society's Philosophical Transactions.

The connection of Mr. Lawes with the Royal Agricultural Society was naturally a close one. He became a member of the

* *Herts Guardian*, July 28, 1855. Also *Gardeners' Chronicle and Agricultural Gazette*, July 15, 1871, p. 918.

Council in 1848, and was afterwards a vice-president and trustee. In 1893 the presidency of the Society was offered to him, but declined on account of his advancing years. In the Journal of the Society the greater number of the reports on the Rothamsted agricultural investigations have been published; forty-six reports had thus appeared before the year 1900. In 1876 he took an active part in arranging for the commencement of the field experiments conducted by the Society at Woburn, in Bedfordshire. These experiments consisted in repetitions of the experiments at Rothamsted upon the continuous growth of wheat and barley with known manures, the experiments, in this case, being made upon a purely sandy soil; they also included rotation experiments designed to test the manurial value of cattle foods. These experiments were conducted on the Duke of Bedford's estate, and at his expense.

The relations of Mr. Lawes with the Chemical Society were also intimate. He became a Fellow in 1850, and was elected to the Council in 1862. The chief part of the chemical work done in the Rothamsted laboratory was communicated to this Society, and about twenty-two lectures and papers by Lawes and Gilbert, and other Rothamsted workers, appear in the "Journal" and "Transactions."

Mr. Lawes was a member of the Royal Commission appointed in 1857 "To inquire into the best mode of distributing the sewage of towns, and applying it to beneficial and profitable uses." Two members of this Commission, Lawes and Way, conducted for several years important experiments on sewage irrigation at Rugby. The investigation dealt with the quantity and composition of the grass receiving varying amounts of sewage, and its value as food for fattening oxen and milking cows, including the composition of the milk obtained. The effluent waters from the irrigated fields were also analysed, and the formation of nitrates in large quantities was demonstrated. The final report was published in 1865.

The aid of Rothamsted was again sought by the Government in 1863, the object in this case being to ascertain whether the malting of barley resulted in any increase of its value as a food. A considerable bulk of barley was divided into two lots, one of which was malted, and the loss in dry matter ascertained; feeding experiments were then made, in which the nutritive effect of a given weight of barley was compared with that shown by the quantity of malt which could have been produced from it. The trials with oxen, sheep, and pigs, were made at Rothamsted, and those with milking cows at Rugby. The full report was presented to Parliament in 1866.

While the formal reports on the Rothamsted investigations were to a large extent the work of Dr. Gilbert, Mr. Lawes was himself an active writer on agricultural subjects. In middle life he was a frequent con-

tributor of short papers to agricultural newspapers and periodicals, both English and American; he also lectured from time to time to agricultural associations. His writings were always marked by great originality, they were also very practical in character. When bringing forward the results of recent scientific inquiries, he would avoid as far as possible the use of scientific language, and speak as a farmer to farmers. The fertility of the land and its relation to landlord and tenant, and the manure value of foods, with the compensation due to an outgoing tenant for unexhausted manures, were subjects which he made peculiarly his own. For many years he sent annually to the *Times* newspaper, in the early autumn, an estimate of the quantity of wheat yielded by the preceding harvest in this country. This estimate was based on the produce of the standard plots in the experimental wheat field at Rothamsted; as the produce here was over or under the average, so it was assumed would be the general produce of the country. The estimates thus made proved generally to be near the truth.

For his great services to agriculture Mr. Lawes was created a baronet by the Queen in 1882. The degree of LL.D. was conferred on him by the University of Edinburgh in 1877; D.C.L. by Oxford in 1893; and Sc.D. by Cambridge in 1894. He received the Legion of Honour from Napoleon III.; he was also a Chevalier du Mérite Agricole. He was elected a corresponding member of the Institute of France in 1879. In 1863, he received a Gold Medal from the Russian Government. In 1881, the German Emperor awarded a Gold Medal for Agricultural Merit to Lawes and Gilbert.

Sir John Lawes early conceived the idea of perpetuating the Rothamsted investigations by placing the laboratory and fields in the hands of trustees with a permanent endowment for their maintenance. He first spoke of this in his speech at the opening of the new laboratory in 1855. In 1872 he publicly announced that he had set aside £100,000 for this purpose. By deeds executed by him in February, 1889, the laboratory and experimental fields were leased to Sir John Lubbock, William Wells, Esquire, and Sir John Evans, as trustees, for 99 years at a peppercorn rent. To the same trustees he covenanted to pay the sum of £100,000, the interest on which was to be applied to the maintenance of agricultural investigations under the direction of a Committee of nine persons, of whom four were to be nominated by the Royal Society, two by the Royal Agricultural Society, one by the Linnean Society, and one by the Chemical Society, the owner of Rothamsted being always a member of the Committee. The appointment of new trustees when required was vested in the Royal Society. The Managing Committee were at once appointed. They consisted of Sir John Evans, Dr. Hugo Müller, Sir Michael Foster, and Sir W. T. Thiselton Dyer, nominated by the Royal Society; Sir John H. Thorold,

and Charles Whitehead, Esq., nominated by the Royal Agricultural Society; William Carruthers, Esq., nominated by the Linnean Society; Prof. H. E. Armstrong, nominated by the Chemical Society; with Sir John Bennet Lawes. Under this Committee, with but few alterations in their constitution, the direction of the work at Rothamsted has since proceeded. One provision of the trust deed directs the Committee to send a lecturer from time to time to the United States of America to lecture upon the results of the Rothamsted investigations.

The Jubilee of the Rothamsted Experiments was celebrated on July 29, 1893. The organisation of this celebration originated with the Royal Agricultural Society. At a meeting on March 1, presided over by H.R.H. the Prince of Wales, it was resolved: "That some public recognition should be made of the invaluable services rendered to Agriculture by Sir John Lawes and Dr. Gilbert." A subscription list was opened, and with the contributions received a large boulder of Shap granite was erected in front of the laboratory, bearing the following inscription:—"To commemorate the completion of Fifty Years of continuous experiments (the first of their kind) in agriculture, conducted at Rothamsted by Sir John Bennet Lawes and Joseph Henry Gilbert. A.D. MDCCCXCIII." A large and distinguished gathering was held in front of the laboratory on the afternoon of July 29, the Rt. Hon. Herbert Gardner, M.P., President of the Board of Agriculture, presided. The Duke of Westminster, as President of the Royal Agricultural Society, presented to Sir John Lawes his portrait, painted by H. Herkomer, R.A., and to Dr. J. H. Gilbert, a silver salver. He also presented congratulatory addresses to both Lawes and Gilbert from the subscribers to the fund, each address being signed by H.R.H. the Prince of Wales. The presentation of a large number of addresses from English and Foreign Societies then followed, including one from the Royal Society. Sir John Lawes and Dr. Gilbert then replied.* A few of the words spoken by Sir John Lawes must be quoted. "That afternoon he had to return thanks to that distinguished and brilliant assembly for their kind congratulations to himself and Dr. Gilbert upon the work that they had been carrying on for the last 50 years. When two people were joined together in marriage they could not part, because they were bound together by very solemn ties. But with regard to himself and Dr. Gilbert the case was quite different, Dr. Gilbert could have left him, or he could have left Dr. Gilbert. Their connection, however, had lasted for more than 50 years. What was the cause? Nothing less than mutual love of the work they had been engaged in. He (Sir John) had delighted in the work from the

* The whole of the addresses and speeches will be found in the Report of the Jubilee Commemoration, published by the Royal Agricultural Society.

beginning. All the time he could spare in the midst of many other responsibilities and duties he had given to the work. But with Dr. Gilbert it had been the work of his life. If it had not been for Dr. Gilbert's collaboration their investigations would have been in a very different state to what they were then."

Shortly after the Jubilee celebration Dr. Gilbert received the honour of Knighthood. In September of the same year the Liebig Silver Medal was awarded to Sir John Lawes and Sir Henry Gilbert by the curators of the Liebig Foundation of the Royal Bavarian Academy of Sciences. In the following year, 1894, the Albert Gold Medal of the Society of Arts was presented to Lawes and Gilbert by H.R.H. the Prince of Wales, "for their joint services to scientific agriculture, and notably for the researches which, throughout a period of fifty years, have been carried on by them at the Experimental Farm, Rothamsted."

Something must now be said as to the personality of the remarkable man whose life's work we have attempted to describe. He possessed an extremely vigorous constitution, and when past 85, exhibited but few of the infirmities of old age. His holiday was always spent in Scotland, and deer stalking and salmon fishing were then his chief occupations. At home, all his leisure time was spent on the farm. He was a keen observer, and knew the experimental fields better than anyone else. His interest in agricultural problems never tired, he was continually finding fresh subjects for inquiry. While gifted with a full share of the scientific imagination, he was thoroughly practical in his conclusions. His long experience as a farmer, and the careful attention to economy learnt in business, were of great use to him when he brought the results of scientific investigation before the agricultural world. He took a broad, statesman-like view of all agricultural questions, and was looked up to by the English farmer as his safest guide and his highest authority.

Sir John Lawes seldom took part in public functions, he was not seen at meetings of scientific societies, and took no active part in politics; excepting the hours unavoidably spent on his London business, he lived as far as possible a country life. It was, however, in no sense a secluded life; his correspondence was very large, and the visitors to the Rothamsted experiments were extremely numerous and of all nationalities. They found at Rothamsted a genial host and a ready guide to the fields, where the lessons taught by the experimental crops were described in brief and pithy sentences by one who knew thoroughly the whole history of each plot.

Sir John Lawes by no means confined his attention to science, agriculture, and business; he was a man of active benevolence. The agricultural labourers of Harpenden found in him their best friend. He began to provide allotment gardens in 1852, and before his death the

number had reached 334. In 1857 he built a club room in the gardens. Various co-operative schemes were started for the labourers' benefit; one of these has been immortalised by Charles Dickens, who visited the club room in April, 1859, and afterwards gave an account of what he saw in the first number of "All the Year Round." The welfare of his workmen at his various factories was equally considered. He exercised a wide private benevolence, and in his own parish was never appealed to in vain for any good work.

Sir John Lawes' life was prolonged to an unusual period; he lived and worked and taught through two successive generations. His health remained very good till within about a week of his death. He died at Rothamsted on August 31, 1900, in his 86th year, and was buried at Harpenden. His only son, Sir Charles Bennet Lawes, who has assumed the additional name of Wittewronge, succeeds to the Rothamsted estate.*

R. W.

SIR JOSEPH HENRY GILBERT. 1817—1901.

Joseph Henry Gilbert was born at Hull on August 1, 1817. He was the second son of the Rev. Joseph Gilbert, a Congregational Minister, who had previously held the position of Professor of Classics at the Divinity College, Rotherham. His mother belonged to a well-known literary family, and under her maiden name of Ann Taylor, was a popular authoress of poems for children. The family removed in 1825 to Nottingham, and it was here that the boyhood of Joseph Henry Gilbert was spent. He was first sent to an elementary school taught by a blind lady of great intelligence, and afterwards to a school kept by Mr. Long at Mansfield. In 1832, while at Scarborough, he met with a serious gunshot accident, which permanently deprived him of the sight of one eye, and considerably damaged the other; his general health suffered much from the shock, and it was some years before he was able to resume his studies. During this interval he in 1838 paid a visit to St. Petersburg. In the autumn of 1838 he became a student at the University of Glasgow; here he devoted nearly a year to the study of analytical chemistry in the laboratory

* Some further facts relating to Sir John Lawes, and views of his career, will be found in *Nature*, September 13, 1900 p. 467; *Jour. Roy. Agri. Soc.*, 1900, p. 511; *Trans. Chem. Soc.*, 1901, p. 890; *Agricultural Gazette*, lii., 1900, p. 228; *Agricultural Students' Gazette*, x., p. 37.

of Prof. Thomas Thomson. Materia-Medica was studied under Dr. J. Couper, and botany under Sir W. J. Hooker. He came to London in the autumn of 1839, and continued his studies at University College, where he attended the chemical lectures and practical classes of Prof. T. Graham, and worked for a short time in the laboratory of Prof. Anthony Todd Thomson. He also studied natural philosophy under J. Sylvester, anatomy under Dr. Grant, and botany under Lindley at Chiswick, and made some progress in the German language. In 1840 he went to Germany, and spent a summer session at Giessen, in the laboratory of Prof. Liebig. Here he took the degree of Ph.D.; two other English students, J. Stenhouse and L. Playfair, afterwards to become celebrated as chemists, took their degrees at the same time. On returning to England, Dr. Gilbert renewed his studies at University College, and became class and laboratory assistant to Prof. A. T. Thomson during the winter and summer sessions of 1840–41. In 1842 he left London and became consulting chemist to Mr. Burd, a calico-printer in the neighbourhood of Manchester. The turning point of his life soon arrived. Mr. Lawes had already made his acquaintance in the laboratory of Prof. A. T. Thomson, and being in want of a trained chemist to assist in the agricultural investigations he had commenced at Rothamsted, he, on the recommendation of Prof. Thomson, engaged the services of Dr. Gilbert. On June 1, 1843, Dr. Gilbert entered on his work at Rothamsted. The connection between Lawes and Gilbert thus commenced continued till the death of Sir John Lawes in 1900, a period of fifty-seven years.

The rapid development of the agricultural investigations at Rothamsted after the year 1843 has been already noticed in the preceding account of the life of Sir John Lawes. The value of the work done was largely due to the unremitted labours of Dr. Gilbert. At the opening of the new laboratory in 1855, Mr. Lawes said, "I should be most ungrateful were I to omit this opportunity of stating how greatly I am indebted to those gentlemen whose lives are devoted to the conduct and management of my experiments. To Dr. Gilbert more especially, I consider a debt of gratitude is due from myself and from every agriculturist in Great Britain. It is not every gentleman of his attainments who would subject himself to the caprice of an individual, or risk his reputation by following the pursuits of a science which has hardly a recognised existence. For twelve years our acquaintance has existed, and I hope twelve years more will find it continuing." The testimony borne by Sir John Lawes to his colleague at the end of fifty years of their joint work has been already quoted in the preceding account of Sir John Lawes.

We must now attempt to give some idea of the special part taken

by Sir Henry Gilbert in the Rothamsted investigations. The two leaders of the work were in almost daily consultation, Sir H. Gilbert spending, as a rule, an hour at Rothamsted every day that Sir John Lawes was at home. The plans for new experiments, the results obtained from day to day, and the drafts of the reports in preparation, were thus all discussed by them together. Sir John Lawes directed the agricultural operations in the experimental fields; the execution of the remainder of the work was in the hands of Sir Henry Gilbert. Sir John Lawes contributed to the joint work a thorough knowledge of practical agriculture. His original mind was stored with facts learnt by keen observation and study in the field. A born investigator, he seemed to be continually occupied in the study of agricultural problems. His enterprising and practical spirit impressed its character on the whole of the Rothamsted work. Sir Henry Gilbert supplemented in a remarkable manner the qualities of his chief. His training as an analytical chemist, and his acquaintance with foreign languages and literature, were naturally of great value in research work. His knowledge of colloquial German enabled him in after years to describe the results of the Rothamsted investigations to many foreign visitors. His special mental characteristics also eminently fitted him for the work subsequently carried out. He was both cautious and painstaking to a remarkable extent, desiring to accumulate a great mass of facts before coming to any certain conclusion upon them. His mode of work was also extremely methodical, and the method once adopted, after full consideration, was continued through many subsequent years, thus giving rise to long series of results obtained in a perfectly similar manner. The continuation of the same field experiments for more than fifty years, and the important results which subsequently followed from an examination of the soils so long under definite cultivation, may be cited as examples of Gilbert's method. Under his care, samples of the grain and straw from each experimental plot, in each year, were preserved in the laboratory, and also samples of the ash yielded by each. In later years, when samples of the soils and subsoils of each plot were repeatedly taken, large portions of each sample were also preserved. At his death the number of samples stored for future reference in the laboratory and in the adjoining building exceeded 50,000. The bulk of tabulated records prepared by the clerks at the laboratory was correspondingly large. He thus laid the foundation of much solid work. The same characteristics appeared in his reports. These usually contained a great bulk of numerical statements, set forth in an orderly manner, with not unfrequently only a small proportion of illuminating theory. The recording of observed facts seemed often to satisfy his object as an investigator. When, however, a definite conclusion had been arrived

at it was tenaciously held, and if attacked was vigorously defended. Sir Henry Gilbert was an antagonist who never tired. His controversies with Liebig, on the subject of his mineral theory, and, in later years, with other German investigators, on the source of fat in the animal body, will be well remembered by his contemporaries.

The life work of Sir Henry Gilbert will chiefly be found in the published reports of the Rothamsted investigations, which, at the time of his death, had reached ten volumes; the subjects of these investigations will be briefly noticed at the close of this biography. His work, however, frequently extended beyond the sphere of the Rothamsted experiments. He was Mr. Lawes' scientific adviser, and as such he played an active part in the trials which took place in the Law Courts respecting the alleged infringment of Mr. Lawes' patent. He made reports on deposits of phosphates at home and abroad. He superintended the experiments relating to the disposal of sewage at the time when Mr. Lawes was a member of the Royal Commission of 1857. Other important undertakings will be mentioned presently.

Dr. Gilbert was married in 1850 to Eliza Laurie, daughter of the Rev. G. Laurie. His wife died in 1853. He married a second time, in 1855, Maria Smith, who survives him. Sir Henry Gilbert owed much to his second wife's untiring assistance. The feeble condition of his eyesight obliged him to rely a good deal on clerical help. Both foreign and English papers were read to him by Lady Gilbert, while the greater part of his own work was dictated to an amanuensis. His great pluck and determination, with the assistance thus rendered, enabled him to accomplish a very large amount of work notwithstanding the serious difficulties under which he laboured.

Sir Henry Gilbert was an active member of many scientific societies, a regular attendant at their meetings, and a member of many scientific committees. The Rothamsted investigations undoubtedly gained by the intercourse thus obtained with other investigators, though the time occupied by visits to London was often considerable. Sir Henry Gilbert was elected a Fellow of the Royal Society in 1860. He was the author, with Sir John Lawes, of seven papers in the "Philosophical Transactions." In 1867 he received, with Sir John Lawes, one of the Royal medals for the work done at Rothamsted. He served on the Council in 1886–8. Sir Henry Gilbert joined the Chemical Society in 1841, a few weeks after its formation, became a member of the Council in 1856, and a Vice-President in 1868. In 1882 he was elected President of the Society. Sir Henry Gilbert delivered four lectures before the Society, and was the part author of several other papers. In 1898 a memorable dinner was given by the Society to six Past-Presidents, all of whom had been members of the Society for more than fifty years; of these Past-Presidents Gilbert was

the eldest. The President concluded his address to him by saying: "The Rothamsted results will be for ever memorable; they are unique, and characteristic of the indomitable perseverance and energy of our venerated President, Sir Henry Gilbert."

Of the Linnean and Meteorological Societies Sir Henry Gilbert was also a Fellow, and occasionally read papers at their meetings. He was also a member of the Society of Arts. He became a member of the Scientific Committee of the Horticultural Society in 1868, and for many years regularly attended its meetings.

In his summer holidays the meeting of the British Association for the Advancement of Science was generally attended; his attendance commenced in 1842, and during many years he scarcely missed a meeting, and frequently read a paper describing some of the Rothamsted results. In 1880 he was President of the Chemical Section, and gave as his address: "A Sketch of the Progress of Agricultural Chemistry." A tour on the Continent generally formed part of the summer holiday; agricultural laboratories and experimental stations were then visited, and the Naturforscher Versammlung, and other scientific gatherings, were often attended and papers read before them. In 1871, and the following year, the details of sugar-beet culture were studied in Germany, Austria, and France, preparatory to the commencement of experiments on this subject at Rothamsted.

Three visits were paid to the United States and Canada. In 1882 he attended the meeting of the American Association for the Advancement of Science, at Montreal, and brought before them the recent determinations of nitrogen in the experimental soils at Rothamsted. A tour of nearly three months was afterwards made in the United States. In 1884 he was again at Montreal, at the meeting of the British Association, and afterwards made a second extensive tour through North America. The last visit was paid in 1893, after the celebration of the Rothamsted jubilee, for the purpose of delivering a course of lectures on the Rothamsted experiments, in accordance with a provision of Sir John Lawes' trust deed. Sir Henry Gilbert first attended the Agricultural Congress held in connection with the World's Fair at Chicago; here he had a splendid reception, all present rising and cheering for some time. To this Exhibition at Chicago a large collection of diagrams had been sent from Rothamsted, and for these a medal was afterwards awarded. Sir Henry Gilbert then gave a course of seven lectures at the State Agricultural College at Amherst, Mass., taking as his subject the chief results relating to the crops ordinarily grown in rotation, with those relating to the feeding of animals, obtained at Rothamsted during the previous fifty years. These lectures, in an enlarged form, were afterwards published by the United States Department of Agriculture, and were reprinted, with an intro-

ductory account of the Rothamsted experiments, in the Transactions of the Highland and Agricultural Society of Scotland for 1895.

In 1884 Dr. Gilbert was elected Sibthorpian Professor of Rural Economy in the University of Oxford, and held this office for six years, the full term allowed by the statute. He delivered during this time over seventy lectures on the results of the Rothamsted investigations; these lectures he hoped to publish, but the intention has remained unfulfilled.

In 1885 Dr. Gilbert became an Honorary Professor of the Royal Agricultural College at Cirencester, and delivered an annual lecture during six years; the lectures were published in the *Agricultural Students' Gazette.* They treat in a condensed form of some of the subjects previously discussed at Oxford.

The transfer of the laboratory and experimental fields to the management of a committee appointed under Sir John Lawes' trust deed of 1889 has been already mentioned. After this date the virtual direction of the experiments continued to remain in the hands of Lawes and Gilbert during their joint lives. For the information of the new committee Sir Henry Gilbert drew up a brief report on the investigations hitherto conducted, showing to what extent the results obtained had been already published, and making suggestions as to future work. This report was printed in 1891 for the use of the committee.

The celebration of the jubilee of the Rothamsted experiments in 1893 has been already described in the notice of Sir John Lawes, with the numerous honours subsequently conferred on both Lawes and Gilbert. Dr. Gilbert received knighthood from the Queen on August 11 of that year.

Sir Henry Gilbert was a member of the committee appointed by the Government in 1896 to take evidence and report on the materials used in the manufacture of beer. The committee presented their report to the Treasury in 1899.

He received many honorary degrees. The University of Glasgow made him LL.D. in 1883; Oxford, M.A. in 1884; Edinburgh, LL.D. in 1890; Cambridge, Sc.D. in 1894. He was a life governor of University College, London; a Corresponding Member of the Institute of France; a Chevalier du Mérite Agricole; and an honorary member of many agricultural societies at home and abroad.

With a life so filled with many labours it need hardly be said that Sir Henry Gilbert was possessed of a robust constitution. He, however, suffered at times from over-brainwork, and his frequent excursions abroad were really needed to maintain a healthy tone. In later years he suffered much at times from internal pain, the precursor, probably, of his last illness. The death of Sir John Lawes in 1900 was naturally a great shock to him. He was fairly vigorous, however, during the

next summer, but was taken seriously ill during a visit to Scotland, and returned home with difficulty. He died at Harpenden on December 23, 1901, in his 85th year.* R. W.

THE INVESTIGATIONS OF LAWES AND GILBERT.

The Rothamsted Agricultural Station was the *first* of the many Agricultural Research Stations now in existence; the only earlier work of the same kind was that carried out for some years by Boussingault on his farm at Bechelbronn, commencing in 1834.

An extensive and long-continued series of field experiments upon the principal agricultural crops is the most striking feature of the Rothamsted work. The trials commenced with turnips and wheat, and soon extended to many other crops, till nearly 40 acres were occupied by these experiments. In each case the same crop was grown year after year on the same land. Thus, at the death of Sir John Lawes, the fifty-seventh successive crop of wheat had been harvested in Broadbalk field. From the commencement of each field experiment one plot was left entirely unmanured and one received farmyard manure each year. The remaining plots received at first various manures, but in a few years the earliest experimental fields were brought under a continuous system of manuring, and the fields afterwards taken for crop experiments received from the first a uniform treatment. The plan in each case was to supply certain plots every year with the various ash constituents of the crop—called by Lawes and Gilbert "mineral manures"—while other plots received nitrogenous manure in various forms, and others various mixtures of the mineral and nitrogenous manures used separately on the other plots. The plan of manuring adopted in these field experiments was originally intended as a practical test of the "mineral theory" of Baron Liebig; no better scheme could, however, have been chosen for the elucidation of the general problems of the relation of crop, soil, and manure to each other. Experimenting in this way many important facts were brought to light—the capacity of the crop to supply itself with nitrogen from the natural sources of the soil and atmosphere; its capacity to supply itself with ash constituents from the soil; the particular ash constituents most necessary to be applied as manure, and those of which the soil soonest became exhausted; the relative value of various nitrogenous manures, and the effect produced by varying amounts of nitrogen. A comparison of the crops produced by chemical manures with the crop yielded by ordinary farmyard manure was also obtained every year. In some instances the special application of manure was stopped on certain plots after a number of

* For some further information upon Sir Henry Gilbert's life and work see *Nature*, January 2, 1902, p. 205; *Jour. Roy Agric. Soc.*, 1901, p. 347; *Trans. Chem. Soc.*, 1902, p. 625.

years, and the land left unmanured; the effect of the residue of the former manuring was thus made apparent. The produce of each plot was carefully weighed, and at the laboratory the proportion of dry matter and ash was determined, while in selected instances the percentage of nitrogen was ascertained, and the plant ash was submitted to analysis. The great variety of seasons met with in so long a series of field experiments enabled the effect of season upon the weight and composition of the crops to be studied, as well as the effect produced by manures.

In later years samples of the soils and subsoils of the various experimental plots were repeatedly taken and analysed; the accumulation or loss of nitrogen, carbon, phosphoric acid and potash resulting from the particular treatment of each plot was thus ascertained. In the case of the wheat field each plot was provided with a drain-pipe, and the water percolating through the soil was regularly collected and some of its constituents determined by chemical analysis; information was thus gained as to the losses which manured land suffers by drainage.

In order to make the chemical statistics of the experimental crops more complete, the rain was collected in a large rain-gauge, and some of its constituents determined. Three drain-gauges, consisting of three masses of bare soil of various depth, were also constructed to ascertain what proportion of the rainfall passed through the soil; the drainage waters from these bare and unmanured soils were also analysed for comparison with the drainage waters furnished by the soils cropped and manured in Broadbalk field.

Besides the field experiments with individual crops, there was a rotation field in which four systems of cropping were carried out, representing ordinary farm practice. A part of this field was permanently unmanured, another portion received only the important ash constituents of crops, and a third portion the ash constituents together with nitrogenous manures. Here, too, both crops and soil have been submitted to analysis in order to complete the chemical statistics of the experiment. In other fields the simple rotations of wheat and beans, and wheat and fallow have been studied.

In the experiments with meadow land mown for hay, the same conditions of manuring were adopted as with other crops. In this case the continued application of different manures produced a great alteration in the botanical character of the herbage, which became extremely different on different plots. This result led to a systematic botanical analysis of the hay produced by each experimental manure. The aid of Dr. Maxwell Masters, F.R.S., was obtained in this part of the inquiry, which has been continued for many years.

The question whether plants assimilated the free nitrogen of the atmosphere was a subject much debated in the early years of the Rothamsted experiments. Dr. Evan Pugh came to England early in 1857,

and devoted more than two years to the investigation of this subject in the Rothamsted laboratory. The results obtained in experiments with a considerable variety of plants, showed no assimilation of free nitrogen. The chemical statistics of the leguminous crops at Rothamsted, and elsewhere, showed, however, that they contained an extraordinary large amount of nitrogen, the source of which was difficult to explain. In 1886, Hellriegel and Wilfarth proved that leguminous plants assimilated the free nitrogen of the air in considerable quantities, if the soil in which they grew contained certain microbes forming nodules on their roots. The experiments giving rise to this conclusion were repeated at Rothamsted with a similar result. The very different results obtained in the earlier and later experiments at Rothamsted were due to the fact that the plants in the earlier experiments were all grown in burnt soil, and the microbes were thus excluded.

Among the miscellaneous investigations conducted at Rothamsted, may be named those on the relation between the amount of water transpired by plants and their increase in dry matter; the investigation on the composition of the milling products of wheat grain; the investigations conducted for the Government, on the manurial value of sewage; also the chemical study of the "fairy-rings" in meadow land.

The experiments relating to animals were very numerous in the earlier years of Rothamsted work. Trials were made on a large scale of the comparative fattening capacity of different breeds of sheep. The sheep were kept under ordinary agricultural conditions, and the relation between food and increase was carefully ascertained. The trials extended over several years. Numerous feeding experiments of a more scientific character were made on fattening pigs; these received diets containing very varied proportions of albuminoids and carbohydrates. It was found that the supply of a larger proportion of albuminoids than that contained in cereal grains was not attended by a greater increase in live weight. This conclusion was contrary to the scientific opinion then prevalent, which regarded the amount of albuminoids in a diet as a measure of its nutritive value. Feeding experiments on oxen were conducted by Lawes and Gilbert at Woburn.

A very important and laborious piece of work was the determination of the percentage composition of the whole bodies of animals, oxen, sheep, and pigs, of various ages, and in various conditions as to fatness. The proportion of all the organs, and of the butcher's carcase, in the live weight, was ascertained in the case of a large number of animals; and in the case of ten animals, the proportion of water, fat, nitrogenous matter, and ash was determined in every part, and by calculation in the whole animal. The ash was afterwards analysed and its composition determined. The facts thus ascertained still form our chief source of information as to the com-

position of the animals produced on the farm, and the composition of the increase produced during fattening. The experiments on pigs threw much light on the source of fat in the animal body. One young pig was killed and its body analysed. Another pig, from the same litter, was fattened with food of known composition, and then killed and analysed. The composition of the increase obtained whilst fattening was thus ascertained. It was found that when pigs were fed on barley meal, maize, or diets containing pure starch and sugar, the quantity of fat produced was far greater than could be accounted for by the ready-formed fat and the albuminoids of the food, and that large quantities of fat must have been formed from carbohydrates. At that time most German physiologists believed that fat was only formed from albuminoids; the conclusion arrived at by Lawes and Gilbert is now, however, universally admitted to be correct. As a result of their experiments with animals they were able to teach the farmer what amount of fattening increase he might expect from the use of ordinary foods, what proportion of the constituents of the food would be stored up in the animal, and what proportion would appear as manure. Tables were also published showing the weight of butcher's carcase in cattle of any given live weight, in various conditions as to fatness.

In later years, opportunity was taken of the presence of a large herd of dairy cows at Rothamsted to prepare statistics of the food consumed and the milk produced by these animals.

Careful experiments on the relative feeding value of barley, and of the malt made from it, were carried out for the Board of Trade. The process of ensilage was also studied, the losses in the silo determined, and the feeding value of silage compared with that of the original green food preserved as hay, and with other foods. The manure value of cattle foods was repeatedly calculated for the information of the farmer, and tables on the subject were published.

A considerable part of the results obtained at Rothamsted still remains unpublished. The number of papers and reports amounted to 132 in 1901. This is exclusive of very many shorter papers by Sir John Lawes, and of the "Memoranda," published annually. The dates of publication extend from 1847 to 1900. The earliest published paper appeared in the *Gardeners' Chronicle and Agricultural Gazette* of June 14, 1845. Separate copies of the Rothamsted papers have been from the first freely distributed. In later years, complete sets of the reports were prepared by reprinting some of the older publications, and bound copies of the whole were presented to the libraries of Agricultural Colleges and Experiment Stations in various parts of the world. About 200 complete sets were thus prepared, of these 50 were purchased by the English Board of Agriculture.

R. W.

SIR JOHN CONROY. 1845—1900.

Sir John Conroy was the only son of Sir Edward Conroy, and grandson of another Sir John, from whom he may have received the inheritance of an old-fashioned courtliness. His mother was a sister of the late Lord Rosse. He was born in 1845, and spent his boyhood at Arborfield Grange, near Reading, and at Eton. From Eton he went to Christ Church, and became a pupil of the present writer, first in the laboratory of the University, and then in that of the College, which was at that time created by the Dean and Chapter out of the old School of Anatomy, where Kidd, and Acland, and Rolleston had worked and taught. While keenly interested in scientific knowledge, he was from the first a man of wide sympathies and many friends. His chief intellectual interests through life were scientific; but the social, moral, and religious sides of his nature were as fully developed as the intellectual, and as often determined his choice of friends and the bestowal of his time.

Characteristically, the one kind of sport which he enjoyed was the old English sport of fox-hunting, and to this he clung from his boyhood till his strength began to fail. During his mother's lifetime he lived mainly with her, arranging at one time to come to Oxford for two days in the week, and carrying on scientific work partly in Oxford and partly at home. On his mother's death, in 1880, he was offered a lectureship at Keble College by his old friend and Christ Church contemporary, Edward Talbot (then Warden of Keble, now Bishop of Rochester). A few years later he became a tutor of Keble, having in the meantime built a small laboratory within the College, which remains as his gift.

With regard to his earlier life, I may quote the words of an undergraduate contemporary, who knew him from that time to the end of his days:—

"He was not a man who changed much; always the same simple, genial, and entirely modest fellow, a perfect gentleman and a true loyal friend. He never thrust himself or his favourite occupations (which were already scientific) upon his friends, and I think we were a little surprised to find how able a man in his own department we had amongst us in undergraduate life."

Conroy held the same high place in the affection of his colleagues both at Keble College, where he was Lecturer for seven years, and at Balliol, where he succeeded Mr. Harold Dixon as Bedford Lecturer in

1887 and was elected a Fellow three years later. To Oxford men the combination of the names of these Colleges suggests some width of sympathy. The religious ideas which Conroy received as an undergraduate and retained through life made his good friends who shared these ideas especially dear to him; but a nature grateful for every kindness and sympathetic with all that is good could offer the most genuine and considerate friendship to men of quite other schools of thought.

As a College tutor in Balliol, which became his home, Conroy had a quite exceptional popularity and success. A fellow-tutor, most capable of judging, writes :—

"The courtesy and the kindness which you remember always made him a peculiar favourite both with his colleagues and his pupils, and not seldom enabled him to mediate between them. I often noticed, too, how gravely men would receive from him a rebuke or expostulation of which they would have thought much less in the mouths of others. They regarded him as untainted with the academical spirit, and as having an experience of the world and of affairs which none of the rest of us had."

During several years before his death Conroy had occasional symptoms of lung disease, which became gradually more grave. Soon after the beginning of the Michaelmas term, 1900, he was advised to seek a warmer climate in Italy. But the disease was not to be vanquished. He died at Rome on the 15th of December, and was buried in the English Cemetery, leaving to his friends the helpful memory of a gracious and noble life.

Conroy's scientific work related chiefly to optical observations and measurements. Although it was his habit, with characteristic modesty, to bring each paper for his old tutor to look over—a welcome task—yet a proper account of the work can only be given by a physicist whose work has been, in part at least, of the same character. The account which follows is due to the kindness and competent knowledge of Dr. A. E. Tutton :—

The scientific work of the late Sir John Conroy consists of 17 memoirs contributed during the years 1873 to 1899, to "The Philosophical Transactions and Proceedings of the Royal Society," "The Journal of the Chemical Society," and "The Philosophical Magazine"; and a further contribution to "Nature" on the subject of the spectrum of the light emitted by the glow-worm.

Like so many physicists, Conroy commenced his scientific work with a contribution to pure chemistry, a memoir on the "Dioxides of Calcium and Strontium" ("Journ. Chem. Soc.," 1873, 808). A new method of preparing these dioxides is described, consisting in the addition of a solution of sodium peroxide to the solution of a calcium

or strontium salt. The crystallised hydrates $CaO_2\ 8H_2O$ and $SrO_2\ 8H_2O$ were obtained, as well as two other hydrates of strontium dioxide crystallising with 10 and 12 molecules of water respectively. It was shown that all these hydrates lost their water at 100°, and became changed into the anhydrous dioxides, which were shown to be buff-coloured or colourless powders soluble in dilute acids without evolution of oxygen.

Conroy's next communication was a physical one, on the "Polarization of Light by Crystals of Iodine" ("Proc. Roy. Soc.," 1876, p. 147). It was observed that the light reflected from the surface of a layer of iodine is polarized, and that the position of the plane of polarization is not of necessity either perpendicular to or parallel with the plane of incidence, but bears a definite relation to some direction within the crystal. The light transmitted by thin films of iodine was also found to be polarized in a plane perpendicular to that of the light polarized by reflection. In the case of crystals, which are rhomboidal plates belonging to the rhombic system, when the long axes of the crystals are perpendicular to or parallel with the plane of incidence, part of the light reflected from their surface is polarized in the plane of incidence and part in a plane at right angles to the long axes of the crystals. It was further shown that when a ray of light passes normally through such a crystal, it is divided into two rays, polarized respectively parallel with and perpendicular to the same crystallographic axis, and the one whose plane of polarization is parallel with this axis suffers the less absorption.

This was followed by two papers on the "Absorption Spectra of Iodine" ("Proc. Roy. Soc.," 1876, p. 45, and "Phil. Mag," 1877). It was shown that the absorption spectra of thin films of solid iodine are very similar to those given by alcoholic solutions of iodine, the whole of the blue end of the spectrum being cut off; and that absorption extends further towards the red as the thickness of the film increases, till at length only light of about wave-length 650 (near C) passes, which in turn is also cut off. Liquid iodine proved to be more transparent, and gave more absorption of the middle part of the spectrum than solid iodine. The action of light on solutions of iodine in alcohol was further shown to resemble that on solid iodine. The absorption of solutions in carbon bisulphide and other liquids of that class proved to bear the same relation to the absorption spectrum of the vapour as the spectrum of the solution of a coloured gas does to that of the gas.

In a memoir "On the Light Reflected by Potassium Permanganate" ("Phil. Mag.," 1878, p. 454), Conroy described a study of the surface colours afforded by the crystals of this salt at varying angles of incidence, and showed that they altered with the surrounding medium,

whether it was air or a liquid such as carbon bisulphide or tetrachloride. The reflection spectra were also studied, and the positions of the absorption bands for varying angles of incidence located, and shown to coincide with the bright spaces in the absorption spectrum of a dilute solution of potassium permanganate.

The "Distribution of Heat in the Visible Spectrum" ("Phil. Mag.," 1879, p. 203) formed the next subject of Conroy's research. From calculations derived from the measurements of Fizeau and Foucault, Lamansky, Knoblauch and Tyndall, it is concluded that the distribution of heat in the normal spectrum differs greatly from that in the dispersion spectrum, and that in the latter the great calorific intensity of the red rays is due to the action of the prism in concentrating these rays upon the face of the thermopile. It was demonstrated that the intensity of the heat in the different portions of the normal spectrum varies but little through a considerable distance, affording some support to Draper's hypothesis that every colour ought to have the same heating effect.

There next followed five papers concerning "Some Experiments on Metallic Reflection" ("Proc. Roy. Soc.," 1879, p. 242; 1881, p. 486; 1883, p. 26; 1884, pp. 36 and 187). In the first, determinations of the angles of principal incidence and principal azimuth, of red light reflected from polished surfaces of gold, in contact with different media, air, water, and carbon bisulphide, are described. The results confirmed Sir David Brewster's opinion that the value of the angle of principal incidence may be taken as indicating the refractive power of a metal.

In the second paper, a continuation of the experiments for light of other refrangibilities, and for silver plates as well as gold, is shown to have led to the conclusion that Brewster's law—that the tangent of the angle of polarization is equal to the refractive index of the medium—holds good for glass in contact with water and carbon tetrachloride, as well as when it is in contact with air; and in all probability for transparent substances in general. Other conclusions were that in the case of metallic films the principal incidence and the principal azimuth increase with the thickness of the film, showing that more than one layer of molecules is concerned in the act of reflection. Also that light polarized perpendicularly to the plane of incidence penetrates to a greater depth than that polarized in the plane of incidence.

In the third and fourth papers the "Amount of Light reflected from Metallic Surfaces" is discussed. The method employed was to compare photometrically the amount of light reflected from a polished metallic surface, inclined at different angles, with that which fell directly on the photometer when the reflecting surface was removed. The experiments showed that the formulæ generally received for metallic reflection are approximately correct, but that the actual

intensity of the reflected light is always less than the theoretical intensity, and that probably three constants are necessary to define a metal optically. In the fifth communication on this subject similar results obtained with films of silver deposited on glass are described.

Another memoir, arising out of the work on metallic reflection, is entitled "A New Photometer" ("Phil. Mag.," 1883, p. 423). In it Conroy describes a modification of Ritchie's photometer, for which twice the accuracy of Bunsen's disk is claimed. Instead of the ordinary form of Ritchie's photometer, consisting of two pieces of white paper fastened to the adjacent sides of a triangular block of wood, each illuminated by one only of the lights to be compared, Conroy places one of the pieces of paper slightly in front of the other and overlapping it to a certain extent, so that, while both are visible to the observer, each is illuminated by only one of the sources of light. When equally illuminated, the edge of the front paper vanishes. With this photometer the results on metallic reflection were obtained.

Next followed an important memoir "On the Polarization of Light by Reflection from the Surface of a Crystal of Iceland Spar" ("Proc. Roy. Soc.," 1886, p. 173). Brewster had found, in the year 1819, that the angle of complete polarization of the light reflected from Iceland spar depends on the position of the reflecting surface, relatively to the crystal axis, and upon the relation of the principal section to the plane of reflection. Conroy's experiments with cleavage faces of Iceland spar in air, water and carbon tetrachloride, confirm the accuracy of Brewster's observations for media other than air, and show also that, as pointed out by Seebeck, the change in the value of the azimuth of the plane of polarization of the reflected light occurs to a less extent when the crystal is in air than when it is in denser media; and that, as the refractive index of the medium increases, the change becomes greatly augmented. It was demonstrated that the facts of the case are accurately represented, for air or water as media, by Brewster's formula for the angle of polarization—$A' = A + \text{Sin}^2\alpha\,(A'' - A)$, in which A and A″ are the maximum and minimum polarizing angles (that is, in the azimuths of 0° and 90°), and A′ the polarizing angle at any intermediate azimuth.

Three years later there followed a memoir on "Some Observations on the Amount of Luminous and Non-luminous Radiation Emitted by a Gas Flame" ("Proc. Roy. Soc.," 1889, p. 55). The most important conclusions contained in this paper are that the radiation from an Argand gas burner consists of about 1·75 per cent. of luminous, and 98·25 per cent. of non-luminous radiation; and that there is no difference, measurable with a thermopile and galvanometer, between the diathermancy of pure water and of a solution of alum. This latter fact is of considerable practical importance, for it shows that a simple

water cell is just as effective for arresting radiant heat in lantern projection as the alum cell which was formerly considered necessary.

Another memoir, embodying some conclusions of a practical character, was shortly afterwards published in the "Phil. Transactions of the Royal Society" (A, 1889, p. 245), entitled, "Some Observations on the Amount of Light Reflected and Transmitted by Certain Kinds of Glass." It was shown that the amount of light reflected by freshly polished glass varies with the way in which it has been polished, and that, if a perfect surface could be obtained without altering the refractive index of the surface layer, then the amount would be accurately given by Fresnel's formula. Usually, however, the amount differs from that given by the formula to a greater or less extent. The formation of a film of lower refractive index on the glass would account for a defect in the light reflected, and the changes in the amount of light transmitted, and in the angle of polarization, support the view that an excess is to be accounted for by the polishing having increased the optical density of the surface layer. When light passes through a transparent plate, it is obviously diminished by reflection at the two surfaces, and it is further reduced by obstruction within the plate, due to absorption and to scattering, if the plate is not absolutely homogeneous. Conroy shows that for 1 centimetre the loss by absorption amounts to 2·62 per cent. in the case of crown glass, and 1·15 per cent. for flint glass.*

In April, 1891, Conroy contributed to the "Phil. Magazine" a paper "On the Change in the Absorption Spectrum of Cobalt Glass Produced by Heat." Cobalt glass gives an absorption spectrum consisting of three dark bands, in the red, yellow and green. Conroy showed that, on heating the glass, the absorption between the red and yellow bands diminishes, and that the red band moves further towards the less refrangible end of the spectrum. As the glass cools, it recovers its original colour and resumes its original spectrum. Hence the absorption spectrum of cobalt glass varies with the temperature.

"The Refractive Index of Water at Temperatures between 0° and 10°" ("Proc. Roy. Soc.," 1895, p. 228) formed the next subject of research.

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* The paper in the "Phil. Trans.," of which the results are here summarised, had its origin in an inquiry conducted by a Committee of the Trinity House into the relative value of gas, oil, and electricity as lighthouse illuminants. For calculating, from the photometric observations, the intensity of lights shown through lenses and lanterns, it was necessary to make some allowance for loss of light due to its reflection and absorption when passing through glass. But the necessary data could not be found, and Sir John Conroy was asked by the present writer to make the needful measurements, which he did conclusively. Practical inquiries often lead incidentally to new scientific truths, such as was in this case the observation that glass of which the surface is very highly polished transmits less light.

The results of very careful determinations of the refractive index of water between these limits of temperature show that the refractive index increases continuously, with diminution of temperature, down to the freezing point, as stated by Jamin; but that the rate of increase changes at about 4°, the temperature of the maximum density of water, as had been already surmised by Gladstone and Dale.

Conroy's last memoir was a contribution to the "Proc. of the Royal Society" in 1899 (p. 308) "On the Refractive Indices and Densities of Normal and Semi-normal Aqueous Solutions of Hydrogen Chloride and the Chlorides of the Alkalies." The work consisted of very careful determinations of these physical constants at the uniform temperature of 18°. The results are recorded in a table, from which it is clear that both the densities and the refractive indices increase with the molecular weight of the substance in solution, except in the case of potassium chloride, whose refractive index is slightly lower than that of sodium chloride.

In all these researches three things stand out clearly as expressive of Conroy's method of work—namely, the extreme delicacy and neatness of his experimental manipulation, the endeavour to attain the highest accuracy in numerical results, and the lucidity and brevity of the exposition of the conclusions derivable from his researches.

A. V. H.

Henry Augustus Rowland.

HENRY AUGUSTUS ROWLAND. 1848—1901.

By the death of Professor Rowland on April 16, 1901, America lost her leading physicist, and the Royal Society one of her most distinguished foreign Fellows.

Henry Augustus Rowland was born at Honesdale, Pennsylvania, on November 27, 1848. His father, grandfather, and great-grandfather, were all clergymen and graduates of Yale College. He had the misfortune at the age of eleven years to lose his father, who is described as interested in chemistry and natural philosophy. He appears to have been also destined for the ministry, but before going to school for that purpose, he had quite given himself up to chemical experiments, glass-blowing, and the making of apparatus, and was in the habit of delivering experimental lectures to the members of his family.

In 1865, at the age of 16, he was sent to the Phillips Academy at Andover to study Latin and Greek, as a preliminary for entering Yale. This proved extremely distasteful to the young experimentalist, and at his own suggestion he was sent in the autumn of the same year to the Rensselaer Polytechnic Institute at Troy, where he remained five years, and graduated as a Civil Engineer in 1870. At this institute he spent most of his time in designing and constructing physical apparatus with which he made his own experiments. His subsequent achievements are striking testimony, if such were needed, to the value of such practical constructive training in physical education.

Before his twentieth birthday he had decided to devote his life to scientific research; and, realising that his opportunity for the pursuit of science lay in becoming a teacher, after a year in the field as a civil engineer he took a post as instructor in science in a western college from which in the spring of 1872 he returned to the Institute at Troy as instructor in physics. Here he spent three years of hard work in study and research, in addition to his teaching work, and carried out his first important scientific investigations.

His first great paper on magnetic permeability was completed in June, 1873, but was more than once rejected by publishing agencies in America, because it was not understood. In this paper, besides other important points, he clearly stated and formulated for the first time the law of the magnetic circuit, which has since played so large a part in the design of electrical machinery. Failing to get it published in his own country, he at last ventured to send it to Clerk Maxwell, who promptly recognized its merit, and secured its immediate appearance in the *Philosophical Magazine* for August 1873. This work at once gained him European recognition as an investigator of high order, and

his merit was soon recognized at home by his appointment in 1875 as Professor of Physics in the Johns Hopkins University, the Faculty of which was then being organized.

As a preliminary to taking up the work of this new post, he spent a year in Europe at various scientific centres, including several months at Berlin in the Laboratory of Helmholtz. While there he made the very delicate investigation of the magnetic effect of moving charges of electricity, a subject of the most fundamental theoretical importance. He succeeded in obtaining the positive result that was looked for, though many previous investigators had failed; but the difficulty of the experiment is so great that the conclusion has since often been called in question. Various subsequent experimentalists have been able to attain only negative results, though using apparatus apparently more complete and delicate than Rowland's. The original conclusion was however confirmed by Rowland himself at Johns Hopkins in 1889 and again in 1900, and also more recently by others at Harvard, and Paris, and elsewhere.

On his return from Europe in 1876, much of his time was devoted to planning and carrying out the equipment of the new Physical Laboratory at Baltimore. In its arrangement great prominence was given to the equipment of the workshop in machinery, tools, and assistants. Rowland was perhaps the first to recognize the great importance of a well-equipped workshop for the execution of original investigation, and he intended from the first that most of his energies should be directed in this channel.

His first important investigation at his new post was the determination of the absolute value of the British Association unit of electrical resistance. According to Kohlrausch's results in 1870, the standards constructed by the Electrical Standards Committee of the British Association in 1863–4, to represent 10^9 C.G.S. units of resistance, were 2 per cent. too high, while according to the work of Lorenz in 1873 they were 2 per cent. too low. Rowland's paper contains an able criticism of the old experiments, and a clear account of the way in which he was enabled to secure results which were probably the most accurate achieved up to that time. His value for the British Association unit was $\cdot 9912 \times 10^9$ C.G.S., which is within 0·5 per cent. of the value now adopted. His next work was the redetermination of the value of the Mechanical Equivalent of Heat, which was presented to the American Academy in 1879, following close on Joule's final results of 1878. This paper, in which he repeats a familiar laboratory experiment on something of an engineering scale, well illustrates his constructive ability in the design of apparatus, and his experimental insight into the inherent difficulties of a problem and the details requiring special attention for the obtaining of accurate determinations.

He was the first to point out the importance of reducing the results from the scale of the mercurial to that of the air thermometer; and for this purpose he carried out a subsidiary investigation in which he compared his mercury thermometers with an air thermometer. He found this the most difficult part of the work, and he in fact attributed the greater part of the probable error of his determinations to the uncertainty of this reduction. His comparison of the thermometric scales was however probably the most accurate achieved up to that date; and he gave as the result of this section of his paper a formula for the deviation of the mercury thermometer from the gas thermometer which represents the scale-difference as accurately as it can be represented by a simple type of expression. Subsequent corrections to this part of the work, made by comparing his mercury thermometers with a Paris standard mercury thermometer and also with a platinum thermometer, have altered his original results by only one part in 2,000, which is no more than the probable error of the result from other causes.

His singular freedom from the defect common to experimentalists, of over estimating the accuracy of their own work, is illustrated by the estimate which he himself gave of the probable error of his determinations. He considered that the value which he had obtained for this fundamental constant was probably correct to at least one part in 500, except near the extremity of the range of temperature over which he worked where the great increase of the external heat-loss might have produced a larger error. As a matter of fact his results near the middle of his range agree to less than 1 in 2,000 with the most recent determinations; and although his values of the mechanical equivalent appear to be in error by as much as 1 in 500 near the extremities of his range, his values of the *total heat* of water, which was the quantity directly measured in his method, are probably correct to 1 in 5,000 over the whole range. This achievement greatly surpassed in accuracy all previous attempts in measuring a quantity of heat; it was rendered possible by the excellence of the mechanical design of his apparatus, and by the precautions which he adopted to make the correction for external heat-loss as small as possible and to determine it with accuracy. These precautions enabled him to work over a range of temperature of nearly 40°C., as compared with a range of less than 4°C. employed by Joule in his latest experiments. As a result he discovered for the first time the remarkable fact that the specific heat of water suffers a notable diminution, of nearly 1 per cent., between 0° and 40°C., which has been amply verified by subsequent experimenters, in opposition to the work of Regnault, till then universally accepted, according to which the specific heat increased continuously from 0° to 100°C.

His next great work, that by which his name has become most widely famous, was the invention and construction of the concave

optical grating, which strikingly illustrates the power of mechanical genius directed by theoretical ability. The construction of optical gratings had already in the hands of Rutherfurd reached a high degree of perfection in America; but these instruments could not be employed for photography, or for measurement without the use of lenses, while owing to inaccuracies of ruling and periodic errors, the spectra exhibited "ghosts," and it was impossible to realize the theoretical limit of resolving power. The first difficulty was met by the invention of the concave grating, which was communicated to the Physical Society of London in 1882, and published in the *Philosophical Magazine* for September, 1883. The second difficulty was met by the invention of a simple method of making a perfect screw by grinding, as described by him in the article "Screw" in the ninth edition of the *Encyclopædia Britannica.* Without a perfect screw a perfect grating could not be ruled; but the construction of a screw was after all only a part and that a small one of the difficulty. The perfect screw requires to be perfectly mounted, and worked automatically in such a way as to rule perfectly straight lines at equal intervals; and the perfected apparatus requires to be most carefully studied, so that its residual errors may be automatically corrected during the ruling of the grating. In all these constructive details the mechanical genius of Rowland is exhibited at its best.

The maps of spectra which he has made it possible to produce, by the admirable gratings, otherwise unattainable, which he has distributed at a nominal price all over the world, have done more than any other invention to add to our knowledge of the fundamental science of spectroscopy, and form the most lasting monument of his genius.

The greater part of the next decade was occupied by Rowland and his students and assistants in working out spectroscopic and kindred measurements to the limit of accuracy made possible by the construction of these concave gratings. This involved incidentally an elaborate study of photographic processes for the perfect reproduction and accurate recording of results. It has led to new discoveries, such as the effect of pressure or density of the surrounding atmosphere on the wave-length of a bright line, the relations connecting the frequencies of the various series of lines in the spectrum of an element, and analysis of a line by a magnetic field, which could not have been made without spectroscopes of great resolving power, or without standard tables of wave-lengths.

In his later years Rowland gave more of his time to engineering problems; as was natural, his advice was often sought as regards new departures in the inception of large electrical undertakings. He also invented, and gave much time and attention to developing, a system of multiple telegraphy, which was shown working at the Paris Exhibition in 1900, the year before his death.

As a teacher, it is generally admitted that Rowland did not appeal to the average student, who was incapable of appreciating the point of view of the great experimentalist. A story is told by Prof. Mendenhall of a visit which he paid to the Johns Hopkins Laboratory, to get some information on the method of work. Rowland seemed to have no idea how many students were to work in the laboratory, and when asked what he would do with them replied, "Do with them? I shall neglect them." He taught by example rather than by precept. "Even of the more advanced students only those who were able to brook severe and searching criticism reaped the full benefit of being under him. His enthusiasm and the inspiration of his example were always of the greatest help; his suggestions were invaluable; but his critical powers, his deep insight into any physical problem, were *the* qualities of greatest benefit." The perfect frankness of his criticism was of great value, though it sometimes unintentionally gave pain to the author or student criticised.

Like many other great investigators, his distinguishing characteristics were simplicity and love of truth. He tried to live up to his ideal of the man of science. What that ideal was may best be stated in his own words quoted from one of his addresses at Johns Hopkins University:—"But for myself, I value in a scientific mind most of all that love of truth, that care in its pursuit, and that humility of mind which makes the possibility of error always present, more than any other quality. This is the mind which has built up modern science to its present perfection, which has laid one stone upon another with such care that it to-day offers to the world the most complete monument to human reason. This is the mind which is destined to govern the world in the future, and to solve problems pertaining to politics and humanity as well as to inanimate nature. It is the only mind which appreciates the imperfections of the human reason and is thus careful to guard against them. It is the only mind that values the truth as it should be valued, and ignores all personal feeling in its pursuit. And this is the mind the physical laboratory is built to cultivate."

H. L. C.

ROBERT ETHERIDGE. 1819—1903.

Robert Etheridge, the eldest son of Thomas and Hannah Etheridge, was born at Ross, in Herefordshire, on December 3, 1819. On his mother's side he was descended from the Pardoes, an old Worcestershire family, and was a cousin of Dr. John Beddoe, F.R.S. On the other side, his grandfather, who had been a seaman, was, in later life, the Harbour Master at Bristol. To him Robert Etheridge was indebted for many natural "curiosities" from abroad, and thus, while still a boy, he was led to form a little museum of his own, adding, in course of time, to the nucleus of foreign shells and other objects, a series of dried plants, minerals and fossils, all of which were carefully arranged and labelled.

He received his early education at a private school in Ross, and later on gave assistance to the master, in return for which he was aided in preparing to enter the University at Cambridge. This project, however, was abandoned, and Robert Etheridge proceeded to Bristol, where, after being engaged for a time in tuition in one of the city schools, he gained more lucrative employment in a business house. During this period his interest in natural history was encouraged. He became acquainted with the Honorary Secretary of the Bristol Philosophical Institution, William Sanders, F.R.S.,* who was then actively occupied in making a geological map of the neighbourhood. From this painstaking geologist, who was a friend of De la Beche, Robert Etheridge learned his first lessons in field geology, while to Samuel Stutchbury, who was then Curator of the Museum of Natural History attached to the Bristol Philosophical Institution, and a man "remarkably skilled in the various branches of natural history," Etheridge must have been greatly indebted for assistance in zoological studies. On the retirement of Stutchbury in 1850, Etheridge was appointed to succeed him as Curator, and this post, which definitely introduced him to scientific work, he held for seven years. During this period he was, for five years, lecturer on Botany in the Bristol Medical School.

As early as 1848 he had attended a meeting of the Cotteswold Naturalists' Field Club at Gloucester, and his connection with that Club had considerable influence on his future career. He became acquainted with the Earl of Ducie, and, on an eventful meeting at Tortworth Court, he was introduced to Sir Roderick Murchison, then

* An Obituary of W. Sanders was printed in the "Proc. Bristol Nat. Soc.," ser. 2, vol. i., 1876, p. 503.

Director-General of the Geological Survey. This led to his gaining a permanent position in the museum at Jermyn Street. He was appointed on July 1, 1857, as Assistant Naturalist, "to carry out the directions of the Naturalist (T. H. Huxley); to catalogue and describe the fossils of the Mesozoic and Cainozoic formations for the memoirs and publications of the Survey." At that time J. W. Salter, the Palæontologist, was distinguished for his unrivalled knowledge of Palæozoic fossils. To the higher post of Palæontologist Etheridge succeeded on July 1, 1863, on the retirement of Salter, and for many years he had the chief responsibility in naming the fossils collected during the progress of the Geological Survey, and in aiding the field-officers in correlating the sub-divisions of the strata. "A Catalogue of the Collection of Fossils in the Museum of Practical Geology," drawn up by R. Etheridge, and accompanied by an interesting "Explanatory Preface" by Prof. Huxley, was published in 1865.

The chief work of Etheridge as a palæontologist was in identifying species of invertebrata, and in tabulating the fossils of the British Islands; comparatively few new species were named and described by him.

As President of the Geological Society he delivered, in 1881 and 1882, voluminous statistical addresses on the analysis and distribution of the British Palæozoic and Jurassic fossils; and the substance of these addresses was embodied in his "Stratigraphical Geology and Palæontology," published in 1885. This work was issued as Part 2 of a second edition of John Phillips' "Manual of Geology"; Part 1, treating of "Physical Geology and Palæontology," having been prepared by Prof. H. G. Seeley. Although the original plan of Phillips was followed, this edition was practically re-written, and Etheridge's work consisted of 712 pages, which dealt in much detail with the strata of the British Islands and their fossils.

Since 1865 Etheridge had been busily occupied in the preparation of a full list of the "Fossils of the British Islands, Stratigraphically and Zoologically arranged," but it was not until 1888 that the first volume, dealing with the Palæozoic species, was printed, the publication having been undertaken by the Delegates of the Oxford University Press. The information was brought up to 1886, in a quarto volume of 468 pages. Volumes 2 and 3, containing the Mesozoic and Cainozoic species, remain in manuscript.

In addition to these larger works, Mr. Etheridge had given particular attention to the Rhætic beds, and had published papers on the strata at Aust Cliff, Westbury-on-Severn, Penarth and Watchet. More important, however, was the paper which he communicated to the Geological Society in April, 1867, "On the Physical Structure of North Devon, and on the Palæontological Value of the Devonian

Fossils." The investigations which led to the preparation of this elaborate essay were undertaken at the request of Murchison, because the validity of the Devonian system, in which he, together with Sedgwick and Lonsdale, had taken so great a part, had been assailed by J. B. Jukes. It was a serious task for one man, comparatively fresh to the subject, to attempt, in the course of two or three months, to unravel the complicated geology of North Devon. Mr. Etheridge, although a man of great activity and indomitable energy, felt keenly the difficulties before him. In the end he brought forward a copious array of observations and deductions, which led him to uphold that the succession of the rocks in North Devon and West Somerset was unbroken and continuous; that there was, in fact, no evidence, as Jukes had maintained, of repetition by disturbance and faulting in the strata. By dint of personal research, and with the assistance of local geologists, he compiled a list of the entire fauna and flora then known of the Devonian rocks and Old Red sandstone of Britain, showing the distribution of the species on the Continent, and the range in time of those which occurred in Silurian, or passed up into Carboniferous. He concluded that the Devonian system was "a great life-group," and "equivalent in time with, or chronologically the same as, the Old Red sandstone as a whole."

Although the subsequent researches of Dr. Henry Hicks have thrown great doubt on the continuity of the series of rocks in North Devon, the fact that the Devonian system constitutes "a great life-group" has been confirmed by subsequent investigations. There is, however, yet much to be done in determining among the rocks in this country the division between Devonian and Carboniferous on the one hand, and Devonian and Silurian on the other.

In 1881 Mr. Etheridge resigned his post on the Geological Survey, on being appointed Assistant Keeper in the Geological Department of the British Museum. Here he laboured until 1891, when he retired from the public service.

Mr. Etheridge was elected a Fellow of the Royal Society in 1871, and afterwards served on the Council and as Vice-President. In 1880 the Murchison medal of the Geological Society was awarded to him, and in 1896 he received the Bolitho medal from the Royal Geological Society of Cornwall.

Throughout his scientific career he had frequently been called upon to give expert advice on economic questions relating to coal, water-supply, &c., and during his later years, and to within a short time of his decease, he was engaged as geological adviser to the promoters of the Dover Coal Exploration. He was a hard worker, ever ready to help others, and esteemed by all for his single-minded, unselfish and genial nature.

He died after a few days' illness, the result of a chill, on December 18, 1903, soon after he had completed his eighty-fourth year.

An excellent portrait of him, accompanied by a brief memoir and a list of his published works, appeared in the "Geological Magazine," January and February, 1904; and a portrait was also published in the "Life and Letters of Sir Joseph Prestwich."

H. B. W.

HENRY EDWARD SCHUNCK. 1820—1903.

Henry Edward Schunck was born in Manchester, August 16, 1820. He was the youngest son of Martin Schunck, who, settling in Manchester in 1808, by his ability and industry amassed a fortune as a foreign merchant, and started the works of "Schunck & Co." Martin Schunck's father, an officer in the army of the Elector of Hesse, had fought on the side of the British in the American Revolution.

Edward Schunck was educated at a private school in Manchester. On leaving school he was sent to Germany to study chemistry, as it was intended that he should manage the calico-printing works established by his father. He studied at Berlin, and afterwards became a pupil of Liebig at Giessen, where he graduated Ph.D. After his return from Germany he entered his father's calico-print works, but after a few years he retired from business, and resolved to devote his life to pure science.

It was in Liebig's laboratory that Dr. Schunck made his first investigations on the colouring matters contained in certain lichens from which archil and cudbear were prepared, and he succeeded in isolating the crystalline substance *lecanorin*, whose composition and relationships he determined.

His first paper on colouring matters was communicated to the Chemical Society in 1841, a few months after the founding of the Society, of which he was elected a Fellow in the same year. This research is typical of much of the work which Dr. Schunck afterwards

accomplished; its opening words, indeed, seem to lay out the course of his life's work. "Our knowledge," it begins, "concerning that department of organic chemistry which embraces the colouring matters is of the most imperfect kind. Though many other branches of organic chemistry have been so thoroughly and accurately investigated that little or nothing remains to be known concerning them, this may be called an unexplored field." Into this unknown country Dr. Schunck penetrated, and carried out his explorations with a perseverance and an experimental skill which rapidly won for him a permanent reputation among chemists.

In 1846 Dr. Schunck published his earliest work on the colouring matter of madder, a subject he made his own by investigations carried on for many years. Alizarin, the colouring principle obtained from madder, has been used as a dye from the earliest times; the plant was cultivated by the Romans. Pliny says, "The madder of Italy is most esteemed." "It is a plant," he adds, "little known except to the sordid, and this because of the great profits arising from its employment in dyeing wool and leather." From Pliny's time the cultivation of madder has been an important branch of agriculture in Italy and France. Forty years ago the madder annually imported into England was valued at $1\frac{1}{4}$ million sterling.

Colin and Robiquet first attacked the chemistry of madder, and succeeded in 1827 in separating the crystallized substance alizarin. Other chemists next described two colouring matters obtained from madder, and Shiel in 1846 analysed and assigned formulæ to these substances. In 1848 Dr. Schunck showed that the colouring matter did not exist in the root when freshly taken from the ground, but was formed after the death of the plant. He showed that this was the result of a fermentative change brought about by a material contained in the root itself. He proved that the crystallised alizarin was chemically the same body as the yellow flocculent precipitate thrown down from solutions. His analyses of alizarin and the other constituents of the root first showed their chemical nature and paved the way for the researches of Graebe and Liebermann, who synthesised alizarin. This artificial preparation of alizarin was soon followed by Perkin's discovery, which has made alizarin a commercial product and superseded the growth of madder.

In 1876 Dr. Schunck discovered anthraflavic acid, which he subsequently isolated from the bye-products accumulated in the manufacture of artificial alizarin, and by fusing this acid with potash he obtained flavopurpurin. In conjunction with Roemer he published a series of papers on purpurin and its congeners, and in 1893, in conjunction with Marchlewski, he obtained another colouring matter—rubiadin (a dihydroxy-methyl-anthraquinone)—from the madder root.

In the chemistry of Indigo, Dr. Schunck's researches have also done much to elucidate the formation of the several colouring matters from the leaves of the indigo plant and from woad. In 1853 he succeeded in extracting from the leaves of the indigo plant an unstable glucoside which he named Indican. This glucoside on hydrolysis with acids yields glucose and indoxyl, which, in contact with air, is at once oxidised to indigo. For some years Dr. Schunck cultivated the plant, *Polygonum tinctorium*, in his garden at Kersal, and showed that the colouring matter, identical with the indigo-purpurin of Baeyer, only appears in the mature plant. His experiments were published in a very interesting monograph, illustrated with coloured plates, showing the influence of various reagents in bringing about the formation of indigo in the leaves of this plant.

The last years of his active life Dr. Schunck devoted to the study of the constitution and function of chlorophyll—the green colouring matter of leaves. With much care and ingenuity he devised a method for preparing chlorophyll in the pure state, and then prepared from it an important series of derivatives, among which the most interesting are *phyllotaonin* and *its* derivative *phylloporphyrin*—a body closely allied in chemical behaviour and in its absorption spectrum to *hæmatoporphyrin* obtained from the hæmoglobin of the blood. Dr. Schunck advanced the theory that chlorophyll plays a part in the plant similar to that of hæmoglobin in the animal; the first acts as a *carrier* of carbonic acid as the latter acts as a *carrier* of oxygen.

In all the difficult investigations which Dr. Schunck undertook, it was his aim and delight to prepare the purest possible specimens of the substances he investigated. The laboratory which he built at Kersal gradually became a museum of rare and most beautiful specimens of "colour chemistry." His laboratory was also celebrated for the finely-ornamented room in which he kept his large and valuable library of scientific books. By his will Dr. Schunck bequeathed the contents of his laboratory, including his collections and scientific library, to the Owens College. He also directed that the College should have the use of the laboratory and the adjacent buildings and garden, under certain conditions, for twenty-five years. Dr. Schunck's executors have agreed to allow the College to remove the laboratory to a site on the College premises adjoining the "Schorlemmer" organic laboratory, where it is now being erected as a permanent memorial to Dr. Schunck. In accordance with his wishes the "Schunck" Laboratory will be used exclusively for research work.

The gift of his collections and library to the Owens College fulfils a purpose initiated some years ago, when Dr. Schunck presented the College with £20,000 for the endowment of chemical research in Manchester. The Schunck fund has been spent chiefly in the purchase

of apparatus and chemicals used in research, and by way of endowment to graduates to enable them to carry on research work under the guidance of the College staff. Next Session the Schunck Laboratory will be available for such students to work in.

Outside his own laboratory Dr. Schunck was chiefly interested in the Manchester Literary and Philosophical Society, of which he was elected a member on the same day as James Prescott Joule and Lyon Playfair, January 25, 1842. For five years he served as Secretary, and from 1862 he was elected either President or Vice-President of the Society during a period of twenty years. Again, in 1889, he resumed office and served continuously on the Council for eight years. In 1896, under considerable pressure, he accepted the office of President once more, in order to promote unity in the Society. This object accomplished, he begged to be relieved from the burden of office in a touching letter from which a few sentences may be quoted :—

" It is but seldom that, at my age, any man is able or can be " expected to take an active interest in the affairs of an important " Society, such as this. At my age many men can do little more than " write a few almost unintelligible phrases in almost illegible lines. " I can, thank Heaven, do a little more than that. Still the exertion " of doing what I was wont to do becomes great, and the desire for " quiet and repose constantly increases.

" I have been a member of this Society for more than fifty years, " and for the greater part of that time engaged in some official " capacity, either as Secretary, Vice-President, or President. I think, " therefore, the time has come for me to respectfully decline any office " the Society may wish to confer on me. . . . .

" In one respect a change has taken place in the constitution of the " Society which is still in progress. I mean the gradual effacement of " what, without giving offence, may be called the *dilettante* element, " of men who carried on science and literature, not as a profession, but " as an intellectual diversion, and the substitution of men who " cultivate science in a strictly professional spirit. This may be " regretted—I regret it—but considering the great and ever-increasing " specialisation of science, and the difficulties attending its cultivation, " this tendency must be ever on the increase."

Although Dr. Schunck retired from the Council in 1897, he still kept up his interest in the Society, and one of his last acts was to place in the room which had been Dalton's laboratory a marble tablet commemorating the fact. In 1898 the Society bestowed on Dr. Schunck the first "Dalton" medal, a medal which had been prepared in 1864, but not previously bestowed.

Dr. Schunck was elected a Fellow of the Royal Society in 1850, and again found himself with Joule in the same list of selected candi-

dates. Three of his important memoirs on Rubian and its derivatives were printed in the "Philosophical Transactions." He was awarded the Davy Medal of the Royal Society in 1899. In the same year the Victoria University conferred on him the honorary degree of D.Sc.

Dr. Schunck was President of the Chemical Section of the British Association at the Manchester meeting in 1887, and was President of the Society of Chemical Industry in 1896.

In his younger days Dr. Schunck was fond of travel, riding, and billiards. He made many journeys on the Continent, and kept voluminous diaries. Botany was always a favourite study of his, and those who knew him in later life always found him either hard at work in his laboratory, or busy in his greenhouses, or deep in a botanical book by way of relaxation. He had a good memory, and was a storehouse of information which he was always ready to impart. His uniform courtesy and his kindly but shrewd counsel, ever at the service of those who sought it, endeared him to a wide circle of younger men. He gave large sums in charity, but the help bestowed was given in secret. Few men have devoted their lives so unselfishly to the pursuit of knowledge for its own sake.

In 1851 Dr. Schunck married Miss Judith Brooke, of Stockport. He died January 13, 1903, at his home at Kersal, leaving his wife and four children to survive him.

H. B. D.

HENRY WILLIAM WATSON. 1827–1903.

Henry William Watson was the son of Thomas Watson, Esquire, of the Royal Navy. He was born in 1827, and received his early education at King's College, London. In 1846 he entered at Trinity College, Cambridge, and devoted his attention principally to mathematics, in Hopkin's Classes, but not to the entire exclusion of other studies. In 1850 he took his degree as Second Wrangler and Smith's prizeman, and in 1851 was elected a Fellow of Trinity. He held the office of Assistant Tutor of his College for two years, 1851–1853. He then went to reside in London with some not very decided intention of studying law, and was a pupil in the chambers of Mr. Christie, the conveyancer. Legal studies seem to have had little fascination for him, and he returned to mathematics, accepting, in 1854, the post of Second Master in the City of London School, and subsequently that of Mathematical Lecturer at King's College, London. In 1856 he married Miss E. Rowe, of Cambridge, and in 1857 became Mathematical Master at Harrow, then under Dr. Vaughan. He was ordained Deacon in 1856, and received Priest's orders in 1858.

In 1865 he accepted the living of Berkeswell, in the gift of the father of one of his Harrow pupils. At Berkeswell he had more leisure to study on his own account, and from this time, so long as his health lasted, he took a keen interest in applied mathematics, contributing occasionally to scientific periodicals, and being the author, alone or in partnership, of the works mentioned in the sequel. He was always a ready and sympathetic helper in other men's work, and there are many who would gladly acknowledge their obligations to him.

In 1860 and 1861, while still at Harrow, he acted as Moderator, and then Examiner, in the Cambridge Mathematical Tripos. He was again an additional Examiner in 1877.

He was elected a Fellow of this Society in 1881, and in 1883 the University of Cambridge conferred on him the degree of Doctor of Science. The University also appointed him, in 1879, their representative Governor of King Edward the Sixth School, Birmingham. He was one of the Founders of the Birmingham Philosophical Society, and its President for two years.

During the whole of his active life, after leaving Harrow, he gave up much, perhaps too much, of his time to examination work, acting for the Civil Service Commissioners, and occasionally for the University of London, and for some years, ending in 1896, he held the office of Mathematical Examiner to that University.

He published in 1871 a text-book on Geometry (Longman's Series) designed mainly for the use of schools.

In 1876 he published a treatise on the Kinetic Theory of Gases (Clarendon Press), which reached a second edition in 1893. The foundations of this Theory had been laid by Maxwell in his articles on the collision of elastic spheres, "Philosophical Magazine, 1860." Beginning a new subject, Maxwell naturally adopted the simplest hypotheses. For his molecules he chose, in 1860, as a limiting case, smooth perfectly elastic spheres, supposed to rebound on collisions with each other without loss of kinetic energy. Subsequently, in 1868, he started the hypothesis that molecules were centres of force repelling one another according to the inverse fifth power of the distance, no one objecting at that time to instantaneous action at a distance. Also for the sake of simplicity he assumed, as a limiting case, the motions of his molecules to be mutually independent, the chance of any one having its velocities within assigned limits being wholly independent of the positions and velocities of all the others. Nature might have made matter continuous and not molecular. But if molecules existed, they could not, so it is assumed, have mutually related motions.

On these assumptions the distribution of velocities among the molecules was found to be, according to the $e^{-h\Sigma mu^2}$ law, generally known as Maxwell's law, and it led to the doctrine of equipartition of energy.

In the meantime the subject had been treated in Germany with elaboration, but on nearly the same assumptions, by O. E. Meyer, and by Ludwig Boltzmann in a great series of papers beginning in 1867 in the Vienna Sitzungsberichte.

Boltzmann accepted Maxwell's second assumption of independence, and deduced therefrom, in addition to Maxwell's results, the H or entropy theorem, according to which Maxwell's law is not only a sufficient, but a necessary, condition for steady motion. He also gave us the law of space distribution known as the $e^{-2h\chi}$ law, which states that the chance of any group of molecules being in a configuration in which the potential of all the mutual and other forces acting on them is χ, varies as $e^{-2h\chi}$. Such was the state of the theory in 1876.

Watson's task was to a great extent that of summing up the work of his predecessors. Like Boltzmann before, and Tait after him, he accepted without discussion the limiting case assumption of independence. It was not until nearly twenty years later, in the discussion of the H theorem and FitzGerald's objection, that the true nature of the assumption was pointed out. And then, and not till then, it was that Boltzmann announced that he would have to make "eine besondere Annahme."

Watson, however, discusses the possible forms of the molecule, and was the first to introduce the most general conception of it as a system defined by n, generalised co-ordinates and corresponding momenta. In the discussion of the relation of the Theory of Gases to Thermodynamics, as then known, he made considerable advance on Boltzmann's work. Maxwell's hypothesis of the inverse fifth power he did not give *in extenso*, probably not considering it a sufficiently good working hypothesis. It is noteworthy that he refused to accept, though he did not deny, the extension of the $e^{-2h\chi}$ law to intermolecular forces, which is distinctly asserted by Boltzmann.

He had the advantage, while preparing this work, of correspondence with Maxwell on many of the points arising.

In 1877, this time in partnership with Mr. S. H. Burbury, he contributed the article "Molecule" to the "Encyclopædia Britannica," ninth edition. In this article the same theory of gases is explained in outline as in Watson's own book, but the article contains likewise some account of the Diffusion and Viscosity of Gases as deduced from the Kinetic Theory, and a somewhat more extended discussion of the ratio between the two specific heats, and the problems thereout arising.

In 1879, again with Mr. S. H. Burbury as colleague, he published a treatise on the Application of Generalised Co-ordinates to the Dynamics of a Material System (Clarendon Press). It was a work on abstract dynamics. It contained a new definition, fundamental to the theory, of the generalised component of momentum. Also a discussion of the abstract theorems of Bertrand, Gauss, and Thomson, relating to impulsive motion from rest, the two latter theorems being presented in a new form. The theory of kinetic foci, and of least action in the strict sense, given in this work was also in great measure new.

Watson then, again in partnership with S. H. Burbury, published a treatise on the Mathematical Theory of Electricity and Magnetism, of which the first volume "Electrostatics" appeared in 1885, the second, "Magnetism and Electrodynamics," in 1889. As stated in the Preface, this treatise was intended rather as a commentary on Maxwell's great work than as an original investigation. Maxwell cared little for mathematics, except as interpreting experiment, or suggesting lines of investigation. His mathematics, for this reason, presented many difficulties to the student, and were even, in some cases, accused of being inaccurate. Watson and his colleague endeavoured to clear up these difficulties, and in some cases, though but seldom, departed considerably from Maxwell's method. The work was completed before the great extension was given to electrical science by Hertz, Röntgen and other recent investigators. For this reason it did not anticipate the great importance since given to the theory of electrons.

The science of electricity, like chemistry, has undergone and is undergoing very rapid changes, the complete knowledge of to-day being no more than a stepping stone to the results attained to-morrow.

In scientific matters Watson had on the whole a Conservative bias, requiring much deliberation before adopting new methods or lines of investigation. By contrast he was in his political opinions a strong Liberal, of the school perhaps of Sir W. Harcourt rather than of any other modern statesman. His Liberalism was, however, more theoretical than practical, and did not induce him to take any active part in the Parliamentary elections for his division. It did not, in fact, consist in any very strong approval of Liberal measures popular for the time being; still less did it stand in the following of any particular politician. It was a mental state to which he had himself attained, and to which it was desirable that other men should attain, and find rest.

As might have been expected, he was never an extremist in his theological opinions. Extreme opinions did not readily grow in the climate of Cambridge in the middle of the last century. He was the friend of all his parishioners, and knew how to sympathise with opinions that were not his, and with studies and interests that he did not share. So far as his influence extended he was of all things a peacemaker.

S. H. B

ROBERT BALDWIN HAYWARD. 1829—1903.

Robert Baldwin Hayward, M.A., F.R.S., was born March 7, 1829, and died February 2, 1903.

Hayward's early education was obtained at University College School, and afterwards he became a student of University College, London. He there attended the lectures of the mathematical professors, and, in particular, those of the late Prof. De Morgan. He considered himself especially indebted, for his progress in mathematical studies, to De Morgan's lectures and De Morgan's published books. He had a great reverence for De Morgan's intellectual powers and personal character, and was much influenced, in matters of science, by De Morgan's ideas and views.

Hayward graduated B.A. at the University of London in 1847, and gained the Scholarship in Natural Philosophy at that University.

In October, 1846, he came into residence at St. John's College, Cambridge, and had a distinguished career as an undergraduate. In January, 1850, before he had attained the age of 21 years, he was placed fourth in the list of Wranglers in the Mathematical Tripos of that year.

From 1852 to 1855 he was Fellow and Assistant Tutor of St. John's College, and, in 1855, he was appointed Tutor and Reader in Natural Philosophy at the University of Durham. In January, 1859, he left Durham to take up a Mathematical Mastership at Harrow School, to which he had been invited by Dr. Vaughan; and he remained at Harrow, under Dr. Butler and Dr. Welldon, for thirty-four years, retiring in 1893. In January, 1871, he succeeded Dr. Farrar, the late Dean of Canterbury, in the large boarding-house, "The Park," of which he was Master for seventeen years. He examined for the Mathematical Tripos in two successive years—as Moderator in 1868, and as Examiner in 1869. He was elected a Fellow of the Royal Society in 1876.

As an undergraduate, and for some time after taking his degree, Hayward gave his attention more particularly to various branches of Applied Mathematics; but as he grew older his thoughts turned more in the direction of Pure Mathematics, especially mathematical method.

In the year 1856, in the tenth volume of the "Transactions of the Cambridge Philosophical Society," there appeared Hayward's paper on "A Direct Method of estimating Velocities, Accelerations, and all

similar Quantities, with respect to Axes movable in any manner in space." This was probably the first development, by direct vector methods, of the general equations of motion of a body, or system of bodies, referred to moving axes of co-ordinates, and marked a very important step in the progress of the science of theoretical mechanics. In this paper the subject was illustrated by an account of the theory of Foucault's Gyroscope, involving a brief analysis of the problem of the motion of Gyroscopic systems.

This was followed, in 1860, by a paper in the third volume of the "Quarterly Journal of Mathematics," giving a direct demonstration of Jacobi's canonical formulæ for the variation of the elements of a disturbed planetary orbit. In the tenth volume, 1870, of the same journal, Hayward produced an article on the interpretation and proof of Lagrange's equations of motion, referred to generalised co-ordinates, among other points giving a direct explanation of why it is that the time can enter explicitly into the equations of constraint of the system.

In 1890 he published a short text-book, on original lines, on Elementary Solid Geometry; and, in 1892, he produced a more elaborate treatise on the Algebra of Coplanar Vectors and Trigonometry. In the "Mathematical Gazette" of February, 1897, there is an article by Hayward on "Some Semi-regular Solids."

Hayward was a real mathematician, and, throughout his life, had great delight in mathematical study and in mathematical research. He was a very careful reader, and he read extensively. His tone was thoughtful and highly philosophical, and all that he produced was worked out with the greatest possible care and precision.

He took a great interest in the work of the Association for the Improvement of Geometrical Teaching, the first annual report of which was published in 1871. The late Prof. Hirst was the first President of the Association, and Hayward was President from 1878 to 1889. In 1897 the Association changed its name, and became the Mathematical Association, and Hayward was the first Vice-President of the new Association. He had the reputation of being an exceedingly courteous president, very much liked by the members, and he opened up discussion on the papers read at the yearly meetings in a very enlightened and interesting manner.

He was a regular attendant at the meetings of the British Association, and in 1884, accompanied by his eldest son and one of his daughters, he visited Canada, and attended the meeting held at Montreal, under the presidency of Lord Rayleigh, in the autumn of that year.

He was an expert mountain climber, and was one of the original members of the Alpine Club.

Hayward's interests, however, were not confined to science and scholarship. While at Harrow he devoted a great deal of time to local affairs, and for seventeen consecutive years held the position of Chairman of the Harrow Local Board. During the last ten years of his life his residence was at Shanklin, Isle of Wight, where his interest in the general well-being again found scope. He served for a term on the Shanklin District Council, and his great knowledge was placed at the service of the town at an important juncture in its history; the Council was faced with a difficulty about the water supply, and Hayward took an active part in the efforts then made, which secured for the town an ample and wholesome service.

He was an enthusiast for preserving beautiful spots for the public, and, about a year ago, when the undercliff near Shanklin was threatened, he worked hard, and successfully, to preserve it. He also took an active interest in schemes for Technical Education, and in the Free Library movement and its relation to the educational advancement of the country. He was a member of the Executive of the Churchmen's Guild for Shanklin, and on January 23, only nine days before his death, he took a prominent part in a discussion on the Public House Trust Scheme.

Hayward was fortunate throughout his life in the enjoyment of the best of health. He was a man of very even temper, and of a most kindly disposition, and he always had a large circle of friends and acquaintances.

His death was painfully sudden. He attended the funeral of his friend and brother-in-law, Dr. H. W. Watson, who died on January 11, and it was noticed by several of those present that he had the appearance of excellent health. On January 25 he was taken seriously ill, and although there was a partial recovery during the week, he became much worse on the following Sunday, and died the next day.

W. H. B.

NORMAN MACLEOD FERRERS. 1829—1903.

The Rev. Norman Macleod Ferrers was born at Prinknash Park, Gloucestershire, on August 11, 1829; his father being Thomas Bromfield Ferrers. He was educated at Eton and entered Gonville and Caius College in 1847. He was Senior Wrangler in the Mathematical Tripos, 1851, and became first Smith's Prizeman immediately after. After a short period, during which he studied law, in London, and was called to the bar at Lincoln's Inn, he returned to Cambridge and took orders. He was ordained Deacon in 1859 and Priest in 1860, by Bishop Turton, of Ely. He then began to hold in succession many offices in College. He was Dean for five years and became a Senior Fellow in 1861. In 1865, the Rev. C. Clayton resigned the Tutorship of the College on being presented to a living by the Bishop of Ripon. The Master of Caius College then divided the office between Ferrers and the Rev. B. H. Drury.

When the British Association met in Cambridge, in 1862, Ferrers was one of the local Secretaries.

His chief recreations at this period were his walking trips in Switzerland and at home. The present writer has several times accompanied him on these tours. As was then the custom we walked over the hills with our knapsacks on our backs, indifferent to all conveyances and sometimes without having settled where we should stay for the night. That he thoroughly enjoyed them was evident, and no doubt the loss of his walking power later on must have been a great deprivation. He used often to count how many times he had ascended Helvellyn; more than twenty times, he told the writer, and on one occasion he did this twice on the same day. Though so fond of mountains he did not attempt any of the more dangerous ascents in Switzerland, but contented himself with such difficulties as were presented at that time by the Titlis. He also regarded a Christmas trip to Rome as one of the events of his life, a mine of pleasing recollections, as he called it. In returning he travelled *over* Mont Cenis; this was done on sledges on which the diligence was placed after being separated from its wheels.

On April 3, 1866, he married Miss Lamb, daughter of Dr. Lamb, Dean of Bristol and Master of Corpus Christi College, Cambridge. During the following years, and until his election to the Mastership of his College, he resided first in Hills Road, and then for twelve years in Brookside, where all his children were born. Here also he seems to

have given a few private pupils the advantage of residing in his house. In 1876, he was appointed a Governor of St. Paul's School, and in 1885, a Governor of Eton College. From 1855 to 1891 he was the acting editor of "The Quarterly Journal of Mathematics," assisted first by Sylvester, then by Cayley and other distinguished mathematicians. He was elected an F.R.S. in 1877, being admitted on the same evening as the late Emperor of Brazil.

On October 12, 1880, Dr. Guest resigned the Mastership of the College, dying about six weeks after, and Ferrers was elected to fill the vacancy on October 27. He was admitted to the degree of D.D., *jure dignitatis*, along with James Porter, the late Master of Peterhouse, on June 7, 1881. The honorary degree of LL.D. was conferred on him at the University of Glasgow, in 1883.

It was in the winter of 1879 that he felt the beginning of those rheumatic symptoms which afterwards made him a complete cripple. He thought nothing of them then, but no remedies could stop the steady progress of the disease. He died at the Master's Lodge, on January 31, 1903, at the age of 73. The burial service was read in the chapel, crowded to its utmost extent, and at its termination, in accordance with the old custom in many colleges, the dead Master was carried round the Court, preceded by the choristers and followed by the members of the College and other friends. At the Gate of Honour the *Nunc Dimittis* was sung and we bade farewell to the body. His remains were subsequently cremated, and, as we were informed, would finally rest in the chapel.

Ferrers played an important part in University politics, being for more than twenty years a member of the Council. This too was a time which included some momentous periods in the history of the University. He also held the high office of Vice-Chancellor during the years 1884, 1885. He first came on the Council at a chance vacancy in 1865, and had little doubt of being re-elected for a full term of four years at the general election in November, 1866. Here, however, he was doomed to disappointment for, the question of the admission of Non-conformists to Fellowships having in the meantime come to the front, his liberal ideas on that subject were not acceptable to the majority of the electoral roll. This question formed the subject of active discussion during the following years, but the controversy was finally closed by the passing of the Tests Act in 1871. He was again rejected at the election of 1868, but in 1872 the position had changed and he was elected for a full period. Finally, in 1878, he was placed at the head of the poll and retained his seat for sixteen years, when his increasing illness obliged him to decline re-election. The University Act was passed in 1877, and this again brought on a period of statute-making. The tenure of Prize Fellowships was shortened, as Ferrers

thought, unduly. The taxation of the Colleges had to be faced. Ferrers urged that this should be effected by a percentage on the divisible revenues of each College, but the Commissioners insisted on the principle of raising a fixed annual sum from the Colleges collectively. This sum began at £5,203 in 1883 and rose gradually to over £25,000 in 1902.

As a consequence of his position as Tutor and Lecturer, Ferrers was necessarily much employed in examinations. The standard of the papers set in Caius College, under his superintendence, was considered to be high, so that it was generally worth while for a student to consult them as a source of good questions from which something out of the common could be learnt. He was Moderator or Examiner eleven times, more times he believed than any one else recorded in University history.

His first book was called "Solutions of the Cambridge Senate House Problems for the Four Years, 1848—1851." In this he was assisted as joint author by J. S. Jackson, another Caius man and fifth wrangler in his own year.

Ferrers was also the author of a treatise on "Trilinear Co-ordinates," published in 1861. These co-ordinates seem first to have been brought into notice in the University by some chapters in "Salmon's Conics," but there was no regular treatise on the subject. Ferrers book at once became one of the text-books much used for the Tripos examination. There was a second edition in 1866, and a third in 1876. The subject is, however, not now studied to the same extent.

At the request of the Master and Fellows of Caius College, Ferrers edited the "Mathematical Writings of George Green," a man of consummate genius who was fourth wrangler in 1837, and afterwards Fellow of his own College. This important work was published in 1871, and rendered generally accessible a series of memoirs which have remained of fundamental importance in both pure and applied mathematics. These writings have also a special interest as the work of an almost untaught mathematician; a glance at the contents of the volume shows how much of the after progress of discovery had been anticipated by him, or has its roots in his work.

His treatise on "Spherical Harmonics," published in 1877, presented many original features. The theory of ellipsoidal harmonics was first studied by Green and Lamé, who used different methods. In his last chapter Ferrers gives an account of these functions, using both methods and adding things of his own. He also illustrates their application by the problem of the attraction of a heterogeneous ellipsoid.

One of his early memoirs was on Sylvester's development of

Poinsot's representation of the motion of a rigid body about a fixed point by means of a *material ellipsoid* whose centre is fixed and which rolls on a rough plane. This paper was read to the Royal Society in 1869, and printed in the "Transactions." He investigates expressions for the pressure and friction, and arrives at a treatment of the problem different from that of Sylvester, in the course of which some other theorems presented themselves which were not without interest.

His contributions to the "Quarterly Journal" are too numerous to be discussed at any length. A complete list of his papers may be found in the Royal Society's "Catalogue of Scientific Papers." We may, however, mention the headings of a few, to show the varied nature of his writings. In 1861 and 1862, he has a series of notes on trilinear and quadriplanar co-ordinates, the latter being probably preparatory to a treatise on "Quadriplanar Co-ordinates," which he once informed the present writer he intended to publish. Then in 1867, he investigates the envelope of the Simson or pedal line of a triangle, and shows that it is a three-cusped hypocycloid. In 1873, he has an extension of Lagrange's equations. In 1875, he has two good papers on hydro-dynamics. In the first, he supposes that a cylindrical vessel is constrained to move in a given manner with fluid inside and outside. He compares the problem to find the motion of the fluid with that to determine the potential of an attracting film, and finally uses the known results of the second problem to solve the first. In the second paper, he solves the same problem when the cylinder is replaced by an ellipsoidal vessel. The manner in which he treats this problem is different from and simpler than that of his predecessors Green and Clebsch in the same work.

These hydro-dynamical researches were allied to the theory of attractions, and accordingly we find him writing on the latter subject in 1877. The components of the attraction of a solid ellipsoid, whose strata of equal density were similar to the boundary, had been investigated by Poisson. Ferrers gave a method of deducing from these the potential of a solid ellipsoid whose density varies as $x^f y^g z^h$, which is easily applied when the integers f, g, h, are not large. He also explains a new device by which the potential of an ellipsoidal shell may be deduced from that of the contained solid.

Lastly, in 1882, he applied himself to study Kelvin's investigation of the law of distribution of electricity in equilibrium on an uninfluenced spherical bowl. In this he made the important addition of finding the potential at any point of space in zonal harmonics.

The writer is indebted for several of the dates mentioned in the first part of this obituary notice to a brief fragment of an autobiography kindly lent to him by Mrs. Ferrers.

E. J. R.

LUIGI CREMONA. 1830—1903.

Luigi Cremona, whose death occurred on June 10, 1903, was born at Pavia on December 7, 1830. At the age of 18 he served as a volunteer in the War of Liberation, and shared in the defence of Venice up to its capitulation. Returning to Pavia, he entered the University, where he studied mathematics under Bordoni and Brioschi, in company with Beltrami, Casorati and others. After holding minor appointments at Pavia, Cremona, and Milan successively, he became in 1860 Professor of Higher Geometry at Bologna. In 1866 he returned to Milan as Professor of Geometry and Graphical Statics in the University, and remained there until he was called to Rome in 1873, as University Professor of Higher Mathematics, and Director of the Engineering School, which was re-organised under his supervision. These posts he held until the time of his death. As Senator and Member of the Higher Council of Public Instruction (of which he was several times the head) he was able to influence the development of the national education of Italy; and it was he who secured the introduction of projective geometry and graphical statics into the official programme of studies. His official duties at Rome engrossed his time, and after 1879 he published only a few mathematical papers: three of these were contributed in 1884 to the London Mathematical Society, the Royal Society of Edinburgh, and the Royal Irish Academy, respectively. It was in 1884 that he paid a visit to this country, on the occasion of the centenary celebration of the University of Edinburgh.

Cremona's natural genius for geometry was happily stimulated in various ways; primarily, according to his own statement, by the *Aperçu Historique* and *Géométrie Supérieure* of Chasles. When he had mastered the method of projective geometry, he was exceptionally qualified to show the power of analysis and pure geometry in combination; for his early training in analysis under Brioschi must have been thorough, and his own sympathies became more and more attracted by pure geometry. In this respect it is interesting to compare him with Salmon, who maintained the balance between the two methods with remarkable steadiness. Cremona, about 1860, was about equally interested in both: he remained, perhaps, equally capable, but not equally interested. Thus we find that, in later years, he recognized Staudt as the true founder of pure geometry, whereas at an earlier date Staudt's purism had somewhat repelled him.

The change in attitude is already marked in the celebrated memoir on cubic surfaces which in 1866 secured half the Steiner prize offered by the Academy of Berlin, the other half being awarded to Sturm.

This is called a memoir of pure geometry, and it is so in the sense that no explicit analytical formulæ are used in it. But Cremona clearly saw that the propositions of Steiner which he was asked to prove depended in great measure on properties of surfaces of any degree; so he began with an outline of the general theory of surfaces, *assuming* as known the fundamental properties of polar surfaces. Now it is quite true that polar curves and surfaces can be defined in geometrical terms, but this definition is artificial, and the question of degree (which is essential in most of the applications) cannot be decided, except by algebraical considerations, or by an extension of Staudt's theory of imaginary points which is extremely laborious, and not fruitful in results. Thus we cannot help feeling that the memoir begins by a sort of evasion; and every now and then we suspect the author of having translated into a geometrical form a proof obtained by analysis. Nevertheless, the memoir is a splendid contribution to geometry in the proper sense; for even if analytical proofs were supplied for the propositions most easily proved in that way, it would not weaken the impression produced by the whole: we should still feel that the writer is dealing with geometrical facts, and engaged in geometrical speculation. The same may be said of Cremona's use of the method of enumeration; hazardous as it is in the hands of the incompetent, he employed it with great effect in arriving at geometrical conclusions: leaving to others the task of verifying his results in a more rigorous way. In this he was following the example of Chasles, Cayley, Salmon and others.

Cremona did not again compete for the Steiner prize; but it was awarded to him in 1874 in recognition of his geometrical researches. It was indeed well deserved; for he had then published his treatises on plane curves and on surfaces, as well as most of his papers of first-rate importance. Among these are the researches, most closely associated with his name, on the birational transformations of plane and solid space, as well as of curves and surfaces. The most familiar example of a birational transformation of a plane is that of inversion: this is a particular case of the quadratic transformation which, in its normal form, is—

$$x : y : z = y'z' : z'x' : x'y'$$

leading to

$$x' : y' : z' = yz : zx : xy.$$

The first consideration of this appears to be due to Magnus and Steiner; Cremona extended the method indefinitely by observing that if we put $x : y : z = \phi : \chi : \psi$, where ϕ, χ, ψ are polynomials in x', y', z' of the nth degree such that, with a, b, c constant, $a\phi + b\chi + c\psi = 0$ goes through $(n^2 - 1)$ fixed points, there is a one–one correspondence between (x', y', z') and (x, y, z). There is a similar theory for solid

space, but it has not been worked out in detail. Cremona's theory of transformation interested him all his life, and his last published paper (Tr. R. Irish Acad., 1884) is on a transformation of the fourth order in space of three dimensions, the inverse transformation being of the sixth order. His method attracted universal attention, and has proved to be of the highest importance, not only in geometry, but in the analytical theory of algebraic functions and integrals. It is, in fact, an algebraic theory, though it is convenient to state it in a geometrical form, and its author preferred to regard it from a geometrical point of view.

Nearly connected with the foregoing is the representation of surfaces on a plane. Map-drawing is a familiar example, which engaged the attention of Hooke and possibly Mercator, as well as of Lagrange, Gauss, &c. For a one–one correspondence the surface must be unicursal, and this is sufficient; Cremona is associated with Cayley, Clebsch, Nöther and others, in the development of the theory. He also applied it to cubic surfaces, Steiner's surface, various scrolls, and some singular surfaces with cuspidal curves.

Among his minor papers may be noticed those on twisted cubics, unicursal twisted quartics, and the three-cusp hypocycloid. Like all his work they are written in the most clear and attractive style: in fact, he may be compared with Dirichlet in his power of simplifying and illuminating everything on which he wrote, even when the subject was not altogether new.

Mathematical students all over the world are indebted to Cremona for his truly admirable treatises: *Introduzione ad una teoria delle curve piane* (" Mem. Acc. Bologna," 1862); *Preliminari ad una teoria geometrica delle superficie* (ibid., 1866); *Elementi di Geometria proiettiva* (Rome, 1873); *Elementi di calcolo grafico* (Turin, 1874); and *Le figure reciproche della statica grafica* (3rd ed., Milan, 1879). These, and the translations of them into foreign languages, must have greatly helped the progress of the subjects with which they deal; they are lucid, elegant, and stimulating, and are not surpassed in merit by any text-books of their kind.

Cremona was a member of all the leading academies of the world, and received, in May, 1903, from the German Emperor, the order *Pour le mérite*. He was elected Foreign Member of the Royal Society in 1879, but did not make any communications to the "Transactions" or "Proceedings."

Obituary notices of some length by D'Ovidio and Veronese have appeared in the *Rendiconti* of the Academy of Turin and of the Accademia dei Lincei. From the second of these assistance has been derived in the preparation of the present notice; it concludes with a list of Cremona's scientific publications.

G. B. M.

JOSIAH WILLARD GIBBS. 1839—1903.

"Josiah Willard Gibbs was the son of Josiah Willard Gibbs (Y. C. 1809), the distinguished Professor of Sacred Literature in the University from 1822 to 1861, and of Mary Anna (Van Cleve) Gibbs. He was born in New Haven, Conn., on February 11, 1839, and died on April 28, 1903. He was prepared for college at the Hopkins Grammar School, New Haven, and entered the class July 24, 1854. In his College course he won the Berkeley Premium for Latin Composition; 1857, Bristed Scholarship; 3rd Prize Latin Examination, 2nd term Junior year; Berkeley Premium for Latin Composition; 1858, 1st De Forest Mathematical Prize; Clark Scholarship; Latin Oration.

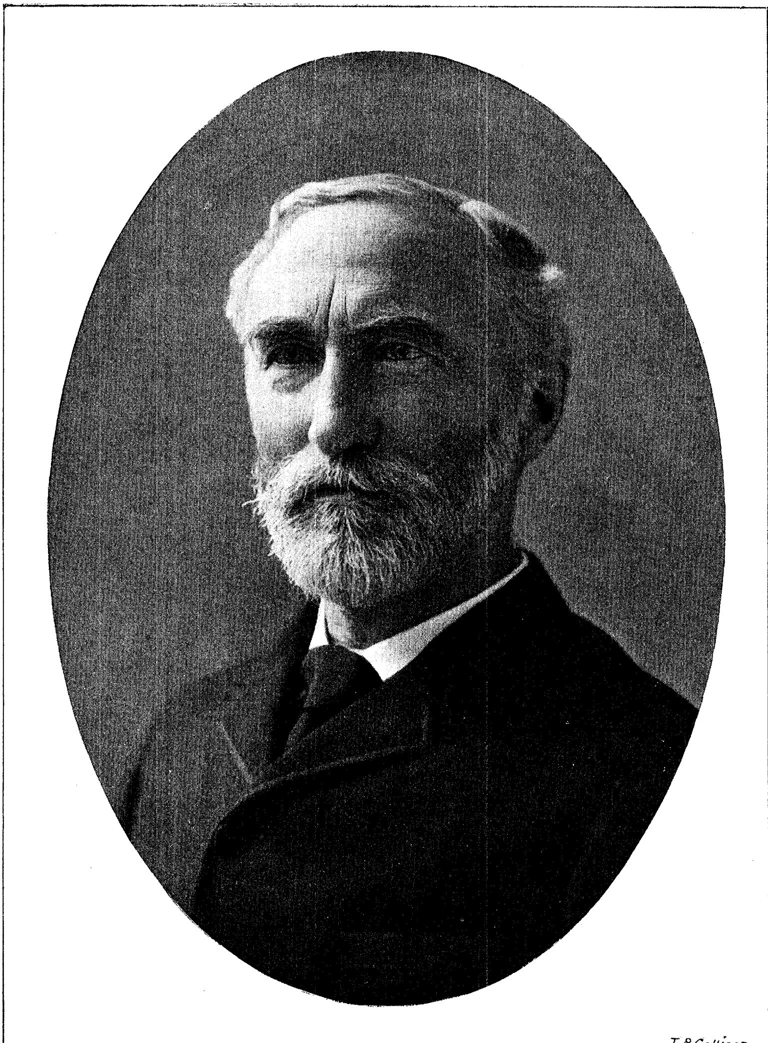
"He occupied the first five years after graduation in 1858 in mathematical and other studies in New Haven. In the autumn of 1863 he became tutor in Yale, and was engaged with the duties of that position until August, 1866, when he went to Europe.

"The winter of 1866–67 he spent in Paris, and the winter of 1867–68 and the following summer, in Berlin, studying especially physics, but devoting a part of his time to mathematics. The winter of 1868–69 he passed in Heidelberg, and the next spring in France, reaching home in June, 1869. In July, 1871, he was elected Professor of Mathematical Physics in Yale."

This synopsis of the early life of the distinguished American Natural Philosopher, whose decease occurred on April 28, 1903, is quoted from the "Yale Alumni Weekly," of May 6.* Not the least of the lessons to be learned from the careers of distinguished men is conveyed by a recital of their early education and activities. It has been remarked that the present case is one of many in which some training in literary studies has helped to mould and brace a mind, destined to contribute materially to the unravelment of the simple fundamental principles that regulate the complex phenomena of Nature.

The prevailing interests revealed in Gibbs' work are those of a mathematician; though his facility in algebra was perhaps slight, and he was most successful when casting his arguments into graphical form. His mind was always straining towards complete general views. His direct geometrical or graphical bent is shown by the attraction which vectorial modes of notation in physical analysis exerted over him, as

* Reference should also be made to the very interesting account by his colleague Prof. H. A. Bumstead, in the "American Journal of Science" xvi, pp. 187–202, which appeared after the present notice was completed.



Josiah Willard Gibbs.

they had done in a more moderate degree over Maxwell, the interpreter of Faraday in this respect; his generalising tendency was illustrated in the formal address, in which he expounded to the American Association the fascinations of the mathematical notations and operations appropriate to this subject, where he could not reach finality until his treatment had got into n dimensions of space. This bent towards exhaustive survey of his subject probably served Gibbs in good stead, by driving him to mathematical completeness in his exposition of thermodynamics, where others would have stopped short with the fragment of the theory that covered the physical applications then prominent or likely to arise. But his tendency to wind up the exposition and regard the account as closed when the logical fabric has been welded together, and to assign a subsidiary place to the details of such particular physical illustrations as then existed—from restraint, be it noted, not from lack of knowledge—retarded for many years the application of his methods by experimenters, to whom the behaviour of actual things is of more interest than the perfection of an abstract formulation of their relations.

The achievement by which Prof. Gibbs will chiefly be remembered is his development, into their full scope, of the fundamental principles which regulate equilibrium and the trend of transformation in inanimate matter in bulk, that is, in general chemical and physical phenomena.

The laws of mechanical equilibrium of material systems, when constitution and physical state remain unaltered, have received attention ever since the ancient beginnings of the science of Statics. Their co-ordination was fruitfully considered by Galileo, who fixed his attention on the indications then current of a general law of compensation in mechanical transformations, revealing itself in the rule that what is gained in force is usually lost in the distance over which it operates. This principle of conservation of work, for all possible virtual displacements, in balanced frictionless systems, was afterwards briefly noted in a form independent of special systems, by Newton; it appeared as a generalisation of the third of his "Axiomata," or fundamental unresolvable laws of inertia and motion, which asserted that to every intrinsic dynamical action of one part of a system on another there is an equivalent (or compensating) reaction of the second part on the first. After this idea of compensation in mechanical work had become more familiar, in connexion with special problems of increasing complexity, during the succeeding century, the thread of Newton's brief generalisation was again picked up by Lagrange, who, in the "Mecanique Analytique," made this principle of work the unique foundation of all statics—that is, of the dynamics of steady systems—thus, as he expressed it, eliminating from the general principles of

the science all accidental considerations peculiar to special types of mechanism. In the wider ramifications of modern abstract dynamics, in which, following the lead of Kelvin, Maxwell, and Helmholtz, its generalised principles are now extended to the elucidation of electrical and other recondite physical manifestations, the query is often put to specify the reaction, to show that Newton's Third Law of Motion is not violated; and the convenient answer is to appeal to Newton's own "Scholium," which practically asserts that, wherever the analysis is based on an energy function, the compensation of action and reaction, considered as work of intrinsic forces, is secured in advance; and we may thus claim to have obtained permanent footing without the necessity of exploration of the concealed working of the system in order to trace out the exact mode of occurrence of this compensation.

The general consideration of the motions generated in unbalanced mechanical systems—a subject the details of which Newton expressly excluded from the "Principia"—led directly, in the hands of Leibniz, Huygens, the Bernoullis, and others, to the recognition that, in the absence of frictional (*i.e.* irreversible) resistances, work that went uncompensated reappeared as *vis viva* of the motion in corresponding amount; so that, by including the kinetic energy, the principle of compensation or conservation still maintains its validity, unless friction is present. We have Helmholtz's own statement that it was early familiarity with these mathematical investigations of the previous century that prompted him to extend the law of conservation into a far-reaching conspectus of all physical phenomena, in his famous essay on the "Conservation of Force" of 1847—waste energy being assumed to take the unorganized kinetic or thermal form—about the same time that the irrefragable evidence for such a universal principle of transmutation of energy had been supplied, unknown to him, by the experiments of Joule.

The whole of the statics of reversible (*i.e.* frictionless) mechanical systems had thus been condensed into the law that the states of equilibrium are defined by the energy being stationary, the criterion of stability being that it is a minimum. A corresponding generalisation was now required for the wider science in which chemical and other non-mechanical sources of power are in operation. Here again the theory will be exhaustive only in its application to reversible types of change. In fact, if the complex of possible transformations is to be reducible to a theory involving analytical functions, reversibility must be an essential feature; without it the courses of individual transformations may be traced, but their features cannot be interlaced into a scheme of relations. The essay of Sadi Carnot, "Sur la Puissance Motrice du Feu," of date 1824, had already pointed out the way, by abstract reasoning based on the idea of complete cycles of processes

such as all mechanical engines execute. Such cycles were, in fact, afterwards appealed to in mechanical statics, by the originators of the doctrine of conservation of energy, to establish the existence of a definite energy-function, on the ground that otherwise work could be obtained in unlimited amount out of nothing. In the hands of Carnot, so far back as 1824, they had been already employed in a wider scope to prove that all reversible heat engines are mechanically equivalent if they work between the same temperatures, on the ground that otherwise work in unlimited amount would be derivable—as he then thought—from nothing. In 1848, W. Thomson, whose notice was attracted to this theory by Clapeyron's graphical exposition of a part of it, seized upon it as affording a new and purely dynamical conception of the notion of temperature—hitherto unconnected with other physical ideas—as a function specifying the capacity of heat for doing work. In the following year he published an exposition of Carnot's doctrine, still reposing, provisionally, on the dogma of the indestructibility of heat; he then professed himself at a loss* to reconcile Carnot's argument with Joule's doctrine of the transmutation of heat into work, so much so as to lead to an unguarded expression of his belief that no case of this had yet been made out, though further experiment was urgently necessary. The difficulties that presented themselves to the pioneers in this new realm are necessarily hard to appreciate by us, to whom so much has, through their labours, become obvious. Yet one weighty circumstance may be recalled. Before Clausius' attention was attracted to the subject, the doctrine of Carnot made, in the hands of James Thomson, the first of its long series of predictions in the entirely new domain of change of physical state†; and no delay ensued before his propositions were verified by his brother's experiments on the lowering of the freezing point of water by pressure. It is in Clausius' great memoir of February, 1850, written from a knowledge of Clapeyron and Thomson alone, that the reconciliation of Joule's and Carnot's principles is effected; so simple yet significant is it, merely the change of the words "derivable from nothing" above to "derivable from completely diffused heat," that in the reprint of James Thomson's memoir on the lowering of the freezing point, in 1851, in the "Camb. and Dub. Math. Journal," only one sentence in the argument had to be altered. The doctrine of Carnot, including most of the results he derived from it, might in

* In his memoir of Joule (*Manchester Memoirs*, 1892) Osborne Reynolds connects this difficulty with the recognition that something is lost when heat merely diffuses; he considers that it was overcome only when the principle of dissipation of energy clearly emerged, which asserted that while the energy is conserved its mechanical availability is in part destroyed.

† Clapeyron had already deduced the corresponding formula for change of boiling point from Carnot's principles.

fact have been quite well developed in a form which would leave open the question as to Joule's principle. Carnot himself before his death in 1832, long previous to this time, had already advanced further; continued reflexion on the phenomena and properties of gases had impelled him to recognise the law of conservation in total energy, as appears very clearly in his manuscript remains published to the world in 1882.

The first suggestion that a dynamical scale of temperature more convenient than Thomson's original one would be gained by taking Carnot's function to be the reciprocal of the temperature, measured from absolute zero by the expansion of any ideal gas, came to him from Joule himself in 1848, who, in reasoning on this subject, presumably attended to his own principle.* In the procedure of Clausius' memoir, the value of Carnot's function was derived from the discussion of an ideal gas, including in its definition Joule's property of absence of internal work, or rather the indications thereof deducible from general considerations and from Regnault's results. It was shown to be the reciprocal of absolute temperature as measured by this ideal body as thermometric substance; and he thence advanced at once to the fundamental simple formula for the efficiency with finite range of temperature. But the precise practical determination of this ideal absolute scale in terms of practical scales based on known actual thermometric substances was a great effort of genius, entirely the work of Joule and Thomson, which amply atoned for Thomson's earlier slip.

The final general form toward which Carnot's principle was to crystallize was first adumbrated by W. Thomson, in 1852, in the statement that the trend of spontaneous change is towards the dissipation or irrecoverable diffusion of the sources of mechanical power. In 1854 Clausius contributed to placing the matter on a simple and quantitative basis by introducing the scalar quantity which he afterwards called the entropy of a system; and in 1865† the law of trend of changes took the final form that in spontaneous change in a system with given energy the entropy must tend always to increase. In this form, viz., expressed by means of entropy, the proposition, quoted from Clausius, is placed by Gibbs at the head of his great memoir, as virtually constituting the culmination of the creative ideas in this subject, what remained being the application of the principle, re-stated by him in far more manageable form, in the ramifications of change of state in actual matter.

* Lord Kelvin, under date February 19, 1852 (Joule's "Collected Papers," i, p. 353) describes Joule's letter to him of December 9, 1848 as giving this result "as the expression of Mayer's hypothesis in terms of the notation of my account of Carnot's theory."

† The passages may be readily found in Hirst's translation of Clausius' earlier Memoirs, published by Van Voorst, 1867.

The trend of Thomson's ideas had led him away towards other problems, such as the cosmical results of his principle, and (1853) the amount of mechanical energy that can be restored from an unequally heated system of bodies in equalising their temperatures. By taking one of the bodies to be of infinite thermal capacity and of temperature θ_0, the energy so restorable would have been determined immediately as $\text{H}—\theta_0 \int d\text{H}/\theta$; as it is necessarily the same for all reversible paths of transformation, this formula leads directly to Clausius' fundamental proposition about entropy.

That function had, in fact, been introduced first of all, at a very early period, by Rankine, who approached it through a special theory of molecules and their atmospheres, and afterwards generalised the argument, in his "Treatise on the Steam Engine," into a chain of abstract propositions, which have never been satisfactorily interpreted or understood.

This sketch of the history of the first stage of the development of abstract thermodynamics is outlined, for the sake of comparison with the next stage of progress. It had been marked by the activity of two great minds working contemporaneously at the same problems; questions of priority have naturally arisen; but we are now far enough removed from the period to appreciate that the merit of each is not interfered with by the work of the other.

Any want of balance in the account above given will be counteracted by an extract from Willard Gibbs' obituary notice (1889) of Clausius, whom he seems to have regarded as in a special sense his master; the extract is appropriate here, as conveying the attitude of mind of the writer towards the history of the science which he had himself reduced into its canonical form.

"But it was with questions of quite another order of magnitude that his [Clausius'] name was destined to be associated. The fundamental questions concerning the relation of heat to mechanical effect, which had been raised by Rumford, Carnot, and others, to meet with little response, were now everywhere pressing to the front. 'For more than twelve years,' said Regnault, in 1853, 'I have been engaged in collecting the materials for the solution of this question:—Given a certain quantity of heat, what is, theoretically, the amount of mechanical effect which can be obtained by applying the heat to evaporation, or the expansion of elastic fluids, in the various circumstances which can be realized in practice?' The twenty-first volume of the 'Memoirs of the Academy of Paris,' describing the first part of the magnificent series of researches which the liberality of the French Government enabled him to carry out for the solution of this question, was published in 1847. In the same year appeared Helmholtz's celebrated memoir, 'Ueber die Erhaltung der Kraft.' For some years

Joule had been making those experiments which were to associate his name with one of the fundamental laws of thermodynamics and one of the principal constants of Nature. In 1849 he made that determination of the mechanical equivalent of heat by the stirring of water, which for nearly thirty years remained the unquestioned standard. In 1848 and 1849, Sir William Thomson was engaged in developing the consequences of Carnot's theory of the motive power of heat; while Prof. James Thomson, in demonstrating the effect of pressure on the freezing point of water by a Carnot's cycle, showed the flexibility and the fruitfulness of a mode of demonstration which was to become canonical in thermodynamics. Meantime, Rankine was attacking the problem in his own way, with one of those marvellous creations of the imagination, of which it is so difficult to estimate the precise value.

"Such was the state of the question when Clausius published his first memoir on thermodynamics, 'Ueber die bewegende Kraft der Wärme, und die Gesetze, welche sich daraus für die Wärmelehre selbst ableiten lassen.' This memoir marks an epoch in the history of physics. If we say, in the words used by Maxwell some years ago, that thermodynamics is 'a science with secure foundations, clear definitions, and distinct boundaries,' and ask when those foundations were laid, those definitions fixed, and those boundaries traced, there can be but one answer; certainly not before the publication of that memoir. The materials indeed existed for such a science, as Clausius showed by constructing it from such materials, substantially, as had for years been the common property of physicists. But truth and error were in a confusing state of mixture. Neither in France, nor in Germany, nor in Great Britain, can we find the answer to the question quoted from Regnault. The case was worse than this, for wrong answers were confidently urged by the highest authorities. That question was completely answered, on its theoretical side, in the memoir of Clausius, and the science of thermodynamics came into existence. And, as Maxwell said in 1878, so it might have been said at any time since the publication of that memoir, that the foundations of the science were secure, its definitions clear, and its boundaries distinct. The constructive power thus exhibited, this ability to bring order out of confusion, this breadth of view which could apprehend one truth without losing sight of another, this nice discrimination to separate truth from error—these are qualities which place the possessor in the first rank of scientific men.

"In the development of the various consequences of the fundamental propositions of thermodynamics, as applied to all kinds of physical phenomena, Clausius was rivalled, perhaps surpassed, in activity and versatility by Sir William Thomson. His attention,

indeed, seems to have been less directed toward the development of the subject in extension than toward the nature of the molecular phenomena of which the laws of thermodynamics are the sensible expression. He seems to have very early felt the conviction that behind the second law of thermodynamics, which relates to the heat absorbed or given out by a body, and therefore capable of direct measurement, there was another law of similar form, but relating to the quantities of heat (*i.e.*, molecular *vis viva*), absorbed in the performance of work, external or internal." [The laws of partition of molecular energy are then compared with Clausius' hypothesis of the Disgregation ; *cf.* his 9th Memoir, §14.]

In its second stage, with which Gibbs is fundamentally associated, the science of thermodynamics widened out into the tracing of the consequences of applying the Carnot-Thomson-Clausius principle of dissipation to natural changes of all kinds : only such changes will be spontaneously possible as do not involve, so to speak, negative or reversed dissipation. From the beginning, the question of the range of the validity of this principle attracted attention.

Lord Kelvin, in his earliest exposition of the "Dissipation of Energy" (April, 1852) already feels justified in the assertion that "restoration of energy is probably never effected by means of organised matter, either endowed with vegetable life or subjected to the will of an animated creature." At a much later date (1882) Helmholtz still considers it an open question whether such a possibility could arise in the very delicate arrangements of the animal organisation. Nowadays, probably, the presumption would be in favour of Lord Kelvin's view ; violation of it would, in fact, necessitate the recognition of "vital force" in a very unambiguous and conspicuous form.

The cosmical results of the dissipation of energy mainly occupied Thomson's attention ; he has nowhere, any more than Clausius, essayed the development of the theory into a doctrine of chemical and physical statics of matter in bulk. The first to emphasize in general terms, by aid of examples, the rich possibilities in this field, was Lord Rayleigh, in 1875, in a lecture on "The Dissipation of Energy."* Later in the same year he made the first quantitative application in this direction, by calculating the dissipation intrinsically involved in the mixture of different gases.† This discussion revealed various clues towards general procedure. The idea of reversible chemical absorption of one of the gases (of carbonic acid for example by quicklime) at once solves the main question proposed, though it is

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* "Roy. Inst. Proc.," 1875 ; "Scientific Papers," i., p. 238. [Horstmann's applications of the principle of maximum entropy (1873) should also be mentioned.]

† "Phil. Mag.," xlix., 1875, p. 311 ; *loc. cit.*, i., p. 242.

not stated whether this novel and direct mode of argument was suggested by the extreme simplicity of the result already obtained through more complex considerations. This investigation, expounded later by Maxwell* in terms of entropy, went far towards completing the doctrine of thermodynamics for interacting gaseous systems, and its results are naturally referred to by Gibbs in that connexion.

The investigations of Gibbs began in 1873, with two papers on the graphical expression of thermodynamic relations, energy and entropy appearing explicitly as variables; of these papers, the later one described the well-known thermodynamic surface, afterwards constructed to scale by Maxwell for water-substance, and gracefully presented by him to its discoverer. It would seem as if it was the study of these surfaces that directed Gibbs towards his general thermodynamic functions, whose minima at any given temperature determine the phases of stable equilibrium of a physical or chemical system at that temperature. Next appeared his great memoir, or rather treatise, published in instalments in the "Transactions of the Connecticut Academy," in 1875 and the three following years, in which this property of minimum in these functions is applied to the most general material systems—going, in his theoretical deductions, far ahead of any experimental procedure that was then contemplated. Thus, advancing beyond Rayleigh's postulated separator of gaseous mixtures by reversible chemical absorption, he introduces into physics, by a stroke of pure theory, the so-called semi-permeable membrane, and the osmotic pressure against it, which has more recently played so fundamental a part in theory, and to some extent in practice, as a mode of expression of the reversible energy-relations between solutions.

The specification of a definite formula for the available energy in a thermodynamic system, in Lord Kelvin's original order of ideas, proved to be a subject not devoid of perplexity. It has been noticed above that the addition to the system of a condenser, or sink of heat, of unlimited capacity at a fixed temperature θ_0, leads to a simple expression for the energy which can be available in this composite system in the process of reversibly reducing all its heat to this temperature, namely $E - \theta_0\phi$, the quantity afterwards termed "motivity" by Lord Kelvin; and that this involves as a corollary that ϕ, the entropy of Clausius, is a definite analytical function of the actual state of the system, which cannot spontaneously increase provided the system is isolated. A hasty confusion between entropy and availability, which occurred in the first edition of Maxwell's "Theory of Heat," was corrected by Gibbs in his early memoir on the thermodynamic surface; and it is, perhaps, not unlikely that he was thereby led to reflect on the question as to the true measure of available energy of the system considered by itself.

* "Ency. Brit.," Article "Diffusion."

If we adhere to the Kelvin order of ideas, we can reason as follows. The dissipation of energy in any material system must be relative to some standard state of the system, for with regard to the absolute zero of temperature all energy is mechanically available. Any group of states of the system, which are mutually convertible by reversible adiabatic processes, are on the same plane as regards dissipation, and can serve as equivalent standard states, those namely of equal entropy ϕ_0. In any working process, for each infinitesimal amount of heat δH or $\theta\,\delta\phi$, which is acquired in a specified state of the system at temperature θ, let the portion δH_0 ultimately arrive at one of these standard states, say the one whose temperature is θ_0; this process involves somehow waste, relative to this standard state, of a part of this energy, originally existing at temperature θ, of amount $\delta H - \theta\,\delta H_0/\theta_0$, that is $\theta\delta\phi - \theta\delta\phi_0$ or $\delta(\theta\phi - \theta\phi_0) - (\phi - \phi_0)\delta\theta$. Thus the total unutilised energy in the given state, relative to this standard, is $\theta\phi - \theta\phi_0 - \int_{\theta_0}^{\theta}(\phi - \phi_0)d\theta$, where ϕ_0 is constant. In this expression the integral is perfectly definite; in it ϕ is to be expressed as a function of θ and the constitution of the system, and θ_0 is the temperature at which with this constitution the value of ϕ is ϕ_0. This dissipation is readily represented on the temperature-entropy diagram for a given constitution of the system.

For isothermal change, in which θ is not altered by the addition of the heat δH, the dissipation for an infinitesimal change is the increment of $\theta\phi - \theta\phi_0$; thus $E - \theta\phi + \theta\phi_0$, of which the last item is now a constant, serves as a function representing the mechanically available energy for changes of state conducted isothermally: its gradient is therefore downward in spontaneous change.

This last result may be reached more directly, following Planck's mode of exposition, by including in the system the surrounding medium in thermal equilibrium with it. The change of the total entropy is now $\delta\phi - \delta E/\theta$, for heat of amount δE has been lost from the surroundings; this must be positive; thus as before it is $\phi - E/\theta$ that tends to a maximum in a system maintained at constant temperature.

But neither of these ways of arriving at the adaptation of the principle of dissipation of energy, or of maximum entropy, to use in the practical case of slow reaction proceeding at constant temperature, is as direct or comprehensive as Gibbs' original analytical statement. As Maxwell remarked, the key to his advance on Kirchhoff and other writers who had previously treated some cases of physico-chemical change in more complex manner, was in definitely introducing the functions of thermodynamics E and ϕ as generalised co-ordinates of the

system. This involved the existence for the system of a unique characteristic relation of total differentials, which might well be called the equation of Gibbs; namely,

$$\delta E = \theta \delta \phi - p \delta v + \mu_1 \delta m_1 + \mu_2 \delta m_2 + \ldots$$

where $\theta\delta\phi$ represents δH, which is not itself the differential of any analytical function, and the other terms represent energy of expansion, of adiabatic chemical change, and of other types, the co-efficients θ, p, μ_1, . . . being intensities which depend only on the state of the system, not on its mass. The principle of Clausius is that, for self-contained systems in which E does not vary, the trend of ϕ must be upwards in spontaneous change; thus at constant temperature the value of $-p\,\delta v + \mu_1\,\delta m_1 + \mu_2\,\delta m_2 + \ldots$ must be negative; therefore at constant temperature the trend of $E - \theta\phi$ must be downwards, contrasting with the case of constant energy when that of $-\phi$ is downwards. The stable equilibria at constant temperature are at the minima of this function. If there is the additional restriction that the reactions occur also under constant extraneous atmospheric pressure, so that p is constant as well as θ, it is the modified available energy $E - \theta\phi + p v$ that tends to a minimum; and a similar simplification obtains if any other force of the system is supposed to be maintained invariable. The variation of this part of the energy, A or $E - \theta\phi$, is wholly available mechanically between states at the same temperature θ; for each temperature it constitutes a potential energy function of the forces, and was in fact afterwards named on that account the free energy by Helmholtz. When states of the systems at different temperatures are compared, the availability must be referred to some standard entropy, as in the discussion above, and the idea becomes complex. Free energies at different temperatures must thus not be compared as available relatively to each other; but $\frac{\partial A}{\partial \theta}$ is equal to the entropy ϕ, and $\theta\delta\frac{\partial A}{\partial \theta}$ is equal to δH, so that the heat capacities of the system are determined directly in terms of A. It had, indeed, been pointed out long before by Massieu, as Gibbs remarked, that this expression $E-\theta\phi$ constituted a single function fully characteristic by itself of the system, over the range of purely physical changes with which thermodynamics was then concerned, in that all the thermal quantities belonging to the system are involved in it and derivable from it by differentiation.

An important development, in this new science of chemical energetics, was the discussion of the number of different states or phases that could exist alongside each other with given materials, as depending on the number of independent constituent substances that are actually interacting; one result of this was the simple and invaluable phase

rule, giving a limit to the number of different substances actually present in terms of the number of phases that can co-exist. In fact, the great service of Gibbs to general chemistry was his definite marking out of the channels within which a scheme of reactions can proceed, by aid of a discussion of the relations of co-existing states or phases of the material, of so general and abstract a character that it could only be carried through effectively by his graphical regional representations, which have shown their power in the application of the method to special problems ever since.

In subsequent parts of the memoir the phenomena of interfacial films were considered in relation to the physical and chemical constitution of the films, leading for the first time to an insight into the causes of their permanence, which has since been expanded, mainly by Lord Rayleigh. Here his essential problem was to try to formulate conditions for interaction, such as would initiate new substances at the interface where two systems are in contact. Not to recur again to the complete establishment of osmotic principles almost before the phenomena had attracted quantitative attention, and to delicate mathematical applications to the effect of stress on chemical equilibrium of crystalline solids in their mother liquid, which make precise James Thomson's early ideas but have hardly yet borne fruit, the memoir ends, in 1878, by the fundamental application to voltaic phenomena. The electromotive force in a reversible cell turns out to be the available energy, not the total energy, liberated per electrochemical equivalent of decomposition, and it is shown by actual cases that this distinction may play an essential part. One brilliant illustration may be quoted; it cannot matter to the available energy at the temperature of liquefaction whether a substance is solid or fused, for the transfer of the latent heat at the uniform temperature can produce no mechanical effect; accordingly electromotive forces should not alter abruptly owing to solidification or fusion, thus explaining a striking fact that had already been experimentally noted.

This electrical application of the theory had been developed independently, by a less general analysis but with extensive experimental confirmations, by Helmholtz in 1882, in ignorance of Gibbs' work. It was not till an even later time that the essential bearings of the theory on general chemistry were thrown into practical light and developed experimentally by van der Waals, van't Hoff, and the other great physical chemists of the Dutch school. In England the work was earlier known. Towards the end of his career (1876) Maxwell contributed an enthusiastic exposition to the Cambridge Philosophical Society, confined to the first part of the memoir, the only part then published, and conveying the opinion that by utilising fully the fundamental concepts of energy and entropy, the author seemed to

him "to throw a new light on thermodynamics"; and, in the early eighties, copies of the memoir were there highly valued, but procured with difficulty. In the abstract of Maxwell's discourse, published in "Proc. Camb. Phil. Soc.," iv, p. 427, the theory is illustrated from F. Guthrie's published experiments on selective precipitation by the introduction of solid substances into a mixed solution, and by observations recently made, perhaps for this purpose, by P. T. Main, on the phases of the triple system composed of chloroform, alcohol, and water; while the simple and natural exposition of the nature of catalytic action was singled out for remark.

It is characteristic of Prof. Gibbs' extreme care for completeness and perfect elaboration, that probably the most interesting and instructive account in existence of this great memoir of over 300 pages is the abstract of 18 pages which he contributed himself to the "American Journal of Science" for December, 1878.

The nineteenth century will be remembered as much for the establishment of the dynamical theory of heat at the very foundation of general physics, as for the unravelment of the nature of radiation and of electricity, or the advance of molecular science. In the first of these subjects the name of Carnot has a place by itself; in the completion of its earlier physical stage the names of Joule and Clausius and Kelvin stand out by common consent; it is, perhaps, not too much to say that, by the final adaptation of its ideas to all reversible natural operations, the name of Gibbs takes a place alongside theirs.

Afterwards Gibbs turned his attention to the electrical theory of light, then in the tentative stage of development, and published in 1882 three papers in which the electrical relations forming the foundation of Maxwell's theory were expounded on the most general formal basis. The medium is taken to be heterogeneous (molecular) in its smallest parts, but of an averaged homogeneous structure as regards elementary regions of dimensions comparable with a wave-length. General linear relations of a formal type between the Maxwellian vectors are assigned, involving the case of rotational media when they are not self-conjugate. The precise part of the electrical basis utilised was the universally admitted general type of formula (Neumann-Maxwell) for the kinetic energy of the (circuital) displacement-currents in the field. The object of the papers was to point out how naturally the laws of optical reflexion, and of double refraction including its dispersion, flow from the electrical ideas as contrasted with the mechanical theory of Cauchy and Green. Thus the analysis is in some respects open to the remark that the electrical foundation is refined and generalized until there is

but little distinctively electrical that is left except the frame; there remains a very general scheme of formal analytical relations, not unlike Hertz's later manner of conceiving the Maxwellian electrical equations, which has to become more restricted and particularised for practical use. In a subsequent paper he contrasted Lord Kelvin's remarkable labile mechanical æther, then recently announced, with electric theory in the same general manner, again laying stress on the formal optical fitness of the system of equations which are the expression of the latter. In all this work we recognise the same penetration and skill, in the formulation and expression of the utmost generality of outlook, which he showed in pure mathematics by his partiality for the study of generalized algebras and vectorial analysis, and which in thermodynamics has largely constituted the strength of his work, though at the same time it has retarded its absorption into the general body of scientific doctrine.

After a period in which Prof. Gibbs' work was much interrupted by ill health, he again appeared before the scientific world early in 1902 as the author of a notable treatise of 207 pages octavo, entitled "Elementary Principles in Statistical Mechanics, developed with especial reference to the Rational Foundation of Thermodynamics," which was published in connexion with the Bi-centenary of the University of Yale. Having had a principal share in evolving the ultimate form of the principles that govern physical and chemical equilibrium, when matter in bulk is considered in terms of its observable properties alone, and having taken care to state them free of all vestige of molecular theory, it was natural that his thoughts should have turned to the less definite problems opened out by the molecular hypothesis of the constitution of matter, which provides a rational base for the axioms on which Carnot, Clausius, and Thomson originally built. While, however, Maxwell and Boltzmann, the creators of the subject here called statistical dynamics, had treated of molecules of matter directly, it is characteristic of Prof. Gibbs that his exposition relates primarily to the statistics of a definite vast aggregation of ideal similar mechanical systems of types completely defined beforehand, and then compares the precise results reached in this ideal discussion with the principles of thermodynamics, already ascertained in the semi-empirical manner. This reversal of order can only profitably be made, as he remarks, after the pioneers of statistical molecular theory have cleared the ground and defined the scope of the relations that are to be explored; but, nevertheless, he holds that the interests of precision invite such a paraphrase of their results. "Moreover, we avoid the gravest difficulties when, giving up the attempt to frame

hypotheses concerning the constitution of material bodies, we pursue statistical enquiries as a branch of rational mechanics. In the present state of science it seems hardly possible to frame a dynamic theory of molecular action which shall embrace the phenomena of thermodynamics, of radiation, and of the electrical manifestations which accompany the union of atoms. Yet any theory is obviously inadequate which does not take account of all these phenomena. . . . . Certainly one is building on an insecure foundation who rests his work on hypotheses concerning the constitution of matter." These remarks, and others of the same tenour, in the preface to the treatise above mentioned, coincide with a general tendency in scientific exposition which is now prominent. But it may be doubted whether there are many who have pondered much on special physical theories, who have not perforce realized the vastness of Nature, so as not to require any reminder that they are merely following out analogies in one aspect of its immense but rational scheme, or improving in one direction our mental outlook on its operations. If we are dissuaded from framing any dynamic theory of molecular action, we shall certainly not progress in welding together the regions of phenomena which Prof. Gibbs enumerates; while to establish, or at any rate trace, their interconnexions, the unattainable ideal of complete knowledge is not required, provided our hypotheses are held in a state of suspense so as not to force us permanently in a wrong direction. And, moreover, recent indications hardly bear out the hopelessness of direct physical speculation in this very subject. The course of progress has rather been usually an evolution from the special simplified theory to the general formal scheme of relationship; an analogy with simple phenomena already understood suggests a special type of hypothesis—so to speak, a calculus adopting that theory as its notation or mode of expression; this is worked out and tested on the facts; it is thus improved and generalised by dropping unessential restrictions—it may ultimately become strong and vivid enough to drop all analogies, and emerge as a purified scheme of relations embracing the sensible phenomena without requiring any forms of expression that are not directly inherent in themselves. Such a scheme of general relations is an improvement on the special analogical theory, provided it does not become too abstract and intangible; but experience may be held to suggest that essential relations restricting the excessive number of the variables in purely descriptive mathematical formulations of experience are, in the first instance, suggested through the analogies of simpler systems. This other point of view may in fact also be put in Prof. Gibbs' own words relating to molecular theory, again quoting from his notice (1889) of the work of Clausius.

"The origin of the kinetic theory of gases is lost in remote

antiquity, and its completion the most sanguine cannot hope to see. But a single generation has seen it advance from the stage of vague surmises to an extensive and well-established body of doctrine. This is mainly the work of three men—Clausius, Maxwell, and Boltzmann, of which Clausius was the earliest in the field, and has been called by Maxwell the principal founder of the science.

"In the meantime, Maxwell and Boltzmann had entered the field. Maxwell's first paper, 'On the Motions and Collisions of perfectly Elastic Spheres,' was characterized by a new manner of proposing the problems of molecular science. Clausius was concerned with the mean values of various quantities, which vary enormously in the smallest time or space which we can appreciate. Maxwell occupied himself with the relative frequency of the various values which these quantities have. In this he was followed by Boltzmann. In reading Clausius we seem to be reading mechanics; in reading Maxwell, and in much of Boltzmann's most valuable work, we seem rather to be reading in the theory of probabilities. There is no doubt that the larger manner in which Maxwell and Boltzmann proposed the problems of molecular science enabled them in some cases to get a more satisfactory and complete answer, even for those questions which do not at first sight seem to require so broad a treatment.

"Boltzmann's first work, however (1866), 'Ueber die mechanische Bedeutung des zweiten Hauptsatzes der Wärmetheorie,' was in a line in which no one had preceded him, although he was followed by some of the most distinguished names among his contemporaries. Somewhat later (1870), Clausius, whose attention had not been called to Boltzmann's work, wrote his paper, 'Ueber die Zuruckführung des zweiten Hauptsatzes der mechanischen Wärmetheorie auf allgemeine mechanische Principien.' The point of departure of these investigations, and others to which they gave rise, is the consideration of the mean values of the force-function and of the *vis viva* of a system in which the motions are periodic, and of the variations of these mean values when the external influences are changed. The theorems developed belong to the same general category as the principle of least action, and the principle or principles known as Hamilton's, which have to do, explicitly or implicitly, with the variations of these mean values. . . . .

"The first problem of molecular science is to derive from the observed properties of bodies as accurate a notion as possible of their molecular constitution. The knowledge we may gain of their molecular constitution may then be utilized in the search for formulas to represent their observable properties. . . . ."

Prof. Gibbs, during his lifetime, was invited to honorary membership of most of the leading learned societies and academies of both hemispheres that pursue physics and mathematics. In particular, he became a Foreign Member of the Royal Society in 1897, and was awarded its crowning distinction, the Copley Medal, in 1901. His thermodynamic writings are accessible in German and in part in French; the curious fatality which has rendered them almost unprocurable, in the language in which they were written, seems happily to be about to cease, through the publication of a memorial edition of his works. We may apply to them his own reflexion on one of his peers:—"Such work as that of Clausius is not measured by counting titles or pages. His true monument lies not on the shelves of libraries, but in the thoughts of men, and in the history of more than one science."

This notice may fittingly be brought to a close by another quotation, expressing the sentiments of the University in which Prof. Gibbs passed his life. "It was not given to laymen to appreciate his services, but all who thought at all of what was being done at this University knew that the roll of Yale teachers was illuminated by a great name; that one of the men who passed in and out so quietly among his colleagues and his students, bearing in his face and forehead such unusual marks of the scholar, was familiarly known in his works wherever in the world the highest scholarship was pursued, and was frequently followed with admiration in new paths of learning. The very presence of such a man as Prof. Gibbs is an asset to a University whose value is beyond measure as an influence upon its members of which they are often unconscious, but by which they are powerfully affected to their good."

J. L.

RUDOLPH VIRCHOW. 1821—1902.

Rudolph Virchow was born of humble parents at Schivelbein, in the Pomeranian province of the kingdom of Prussia, October 13, 1821.

In 1839 he became a student in the Academy of Military Medicine in Berlin. Here he came under the powerful influence of Johannes Müller, who was the intellectual father of many other leaders of scientific thought.

After completing his course in 1844, Virchow escaped the army by becoming assistant to Froriep in the *post-mortem* room of the Charité, and two years later succeeded him as prosector. The fact that he had already given evidence of radical opinions in politics did not help his academical course in the eventful year 1848, and a few months later (May, 1849) he gladly accepted a call from Würzburg to be Professor of Pathological Anatomy. Here he published several original papers, and founded his famous "Archiv f. path. Anat. u. Phys. u. für kl. Med." The early death of his colleague, Reinhardt, left him the sole editor in 1852, and he continued in office until his death. The remarkable results of his early investigations at Berlin and Würzburg—particularly those on thrombosis and embolism, on the white corpuscles and Leuchæmia, on coagulation and on cretinism—were reprinted from the "Archiv" and other periodicals in 1855, and published, with a well-deserved dedication to Robert Froriep, and a characteristic introduction, in which the young pathologist dealt with the attempt to bring about unity in the domain of scientific medicine. In 53 pages he discusses the brain and the will, consciousness and self-consciousness, anthropology and "humanism," the multiplication and heredity of cells, the origin of life, medicine and disease, cellular pathology, heredity, and infection.

A considerable part of this volume is occupied with memoirs on the pathology of the fœtus, and on pregnancy and uterine disorders, a department to which he had been directed while at Berlin by Carl Meyer, whose daughter he married. Although Virchow's "Archiv" was more and more confined to pathology, the subject of clinical medicine continues to appear on the title to the present day, and the editor never quite relinquished the privileges and duties of a physician, particularly in prescribing for his assistants. In 1847, before he left Berlin, he was sent by the Prussian Government to investigate a terrible epidemic of what was then called typhus, but while the disease now known by that name (*Typhus maculosus*, or spotted

fever) was present, the majority of the cases were what was afterwards shown to be a separate disease (relapsing or recurrent fever, *Hunger-typhus*). In the young physician's report he boldly exposed the hardships of the Silesian peasants, the insufficiency of their food, and the shortcomings of the Government.

The result of the researches, at once wide and deep, which occupied Virchow's time from 1844 to 1849 in Berlin, and from 1849 to 1856 in Würzburg, culminated in the publication of his famous lectures on "Cellular Pathology" (published 1855–58), not less remarkable for their clearness of style, their classical proportion and symmetry, than for their learning and originality. The book, of only about 450 pages, was at once translated into every European language, and established the author's position as the foremost pathologist of his time.

It was followed, in 1863, seven years after his recall to Berlin, by the "Krankhafte Geschwülste," in three volumes, the last of which, however, was never completed. This monumental work showed the same wide knowledge of the past history of the subject, the same accuracy and fulness of detail, the same comprehensive judgment, and the same clearness and simplicity of style.* The absence of the chapters which should have dealt with the most important of all new growths, the cancers, was a *hiatus valde deflendus*. It was no doubt due at first to hesitation between the author's own view of the mesoblastic origin of cancer and that propounded by Thiersch, and established by Waldeyer, of their exclusively epithelial origin. As time went on, it became more and more difficult to say anything at once original and sure. After thirty years the problem remains unsolved, to tempt future pathologists endowed with the learning, the insight and the judgment of Virchow.†

During the years which followed, from 1870 onward, no great work appeared from the master's hand, but papers on trichiniasis, craniology, and chlorosis appeared at intervals. He continued his lectures, and still prepared, described and labelled the preparations for his museum, until at length they numbered 23,000. He was still the editor of his own "Archiv," as well as of a collection of treatises on medicine by various hands, which were oddly published as a handbook under his name. But he turned his attention to archæology and the studies which go under the titles of ethnology and anthropology, particularly in the departments of prehistoric sepulture and of craniology.

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* Its relation to the "Cellular Pathologie" may be compared with that of Darwin's volumes on "Animals and Plants under Domestication" to his "Origin of Species."

† Johannes Müller's work on tumours was also left uncompleted, but it was interrupted by the great man's premature death.

He had never ceased to be interested in politics, though he had corrected the immaturity of his early opinions. He entered first the Prussian, and, after the war of 1870, the Imperial German Diet. He became a leader of the Liberal Party, and opposed arbitrary government, military encroachments, and the formation of a German fleet, while he advocated peace, economy and care for the material welfare of the people. He was moderate in language, and went on with his demonstrations and lectures in the Charité while he was under the surveillance of the police, with perfect equanimity. This was in 1867, when political discussions were so bitter that the Prime Minister, Bismarck, challenged Virchow to fight a duel.

Not less useful was his work as a member of the Municipal Council of Berlin, where for nearly forty years he preached, and at last carried out, the sanitary reforms which made one of the most unwholesome of continental cities into one of the best drained and most healthy.

In his later years he was present at many congresses, and presided over the one which met at Berlin. He was made a Member of the Institute of France, and in 1892 received the Copley Medal of this Society. He delivered the Croonian Lecture on the work of Glisson in 1893, and the Huxley Lecture at Charing Cross Hospital a few years later. On the latter occasion he was entertained at dinner by the leading pathologists of the three kingdoms. The President of this Society (Lord Lister) presided, and the President of the College of Physicians (Sir Samuel Wilks) proposed the health of the venerable guest.

Thus, surrounded by all that should accompany old age, with great works completed and still full of activity and interest in life, mellowed by time and wise with the wisdom of experience, Virchow passed his 80th birthday.

In January, 1902, an accidental fall on leaving a tramcar in Berlin caused fracture of the neck of the femur, and, as is frequently the case, he never recovered from the effects of the injury, and died painlessly on September 5th in the same year.

Virchow was small in stature, plain in manner, and without elegance as a speaker. He appeared cold and hard, but he was capable of righteous indignation against injustice or neglect of duty, and was much beloved by his family and intimate friends. He was not liked as an examiner, but as a teacher was punctual, exact, full and instructive. His completed works and his detailed papers were alike admirable for their extent of information as to history and bibliography. He was familiar not only with French English and Italian, but with Latin, Greek, and Hebrew. He did full justice to the merits o English scientific men, particularly to Glisson, Pott, Hunter and Cruikshank, Baillie, and Wilks. He did not shrink from controversy, and firmly sustained his positions against Henle, Rokitansky, Hughes

Bennett and Hueppe; but he was not unmindful of the spirit he inculcated on others in the preface to his collected writings in 1861:—

"No doubt science cannot admit of compromises, and can only bring out the complete truth. Hence there must be controversy, and the strife may be, and sometimes must be, sharp. But must it even then be personal? Does it help science to attack the man as well as the statement? On the contrary, has not science the noble privilege of carrying on its controversies without personal quarrels?"

Virchow's place as a pathologist is in the line of Morgagni, Bichat, Cruveillier and Rokitansky, of Hodgkin, Goodsir, Redfern and Paget. Like many pioneers, he reached a period when he ceased to welcome new discoveries. He never quite accepted, or perhaps appreciated, Darwin's great work, and he scarcely realised the advance of pathology in its bacteriological and experimental departments. But the extent, originality and fruitfulness of his labours place him among the most distinguished men of science in the nineteenth century.

P. H. P. S.

JAMES WIMSHURST. 1832—1903.

James Wimshurst, son of Henry Wimshurst, who designed and built the first two screw-propelled ships, was born in London, April 13, 1832. He was apprenticed to shipbuilding and engineering at the works of Mr. James Mare, now the Thames Iron Works. After some years spent on the staff of Lloyds, he was made chief of the staff of the Liverpool Underwriters' Registry, and ten years later he joined the Board of Trade as Chief Shipwright Surveyor in the Consultative Department at Whitehall, a post from which he retired in 1899 on reaching the age limit. All his life he devoted most of his leisure time to experimental work, and fitted up for himself at his house large workshops equipped with engineering appliances, driven by power. In his workshop at Clapham he built his own electric lighting machinery. About the year 1881 he became interested in influence machines, and built for himself several of the then current types, including machines of the Holtz and Carré patterns. Into the former he introduced

several modifications of a practical kind; but, not being satisfied with any of them, he designed the type of instrument associated with his name, having two circular plates rotating in opposite directions, and having metallic sectors on the outer faces of each. Later, he devised very powerful multiple-plate machines on the same plan, with many original details. He constructed with his own hands more than ninety influence machines, large and small, many of which he presented to his scientific friends. He constructed the gigantic two-plate machine for the Science Collection at South Kensington. Others had cylindrical plates, and one was designed with two ribbons, which travelled past one another in opposite directions. He took no patents for his improvements, a circumstance which he regretted later, not on account of any pecuniary reward that he had sacrificed, but because, in the absence of any patent-rights, he could not exercise any control over the design or construction of inferior machines which were put upon the market in his name. In 1896, when Röntgen made the discovery of the rays emanating from highly-exhausted Crookes' tubes, Wimshurst found his influence machine to be an admirable means of exciting them, and he showed that for screen observation, where a steady illumination is desirable, the steady discharge from one of his eight-plate influence machines was preferable to the intermittent discharge of the usual induction coil. He became exceedingly interested in this application of his machines and in their application in hospitals to produce high-tension discharges for the treatment of lupus and other skin diseases. He was an active Member of the Röntgen Society, to which, as well as to the Physical Society, he communicated several papers. In 1889 he was elected a Member of the Institution of Electrical Engineers, and belonged to various other learned and professional Societies. He was elected a Fellow of the Royal Society in 1898. Exceedingly simple in his own personal tastes and manner of life, he was sincerely generous and hospitable, always willing to aid younger men in any scientific work, and never better pleased than when he could gather a few of his friends around him in his laboratory to spend an evening upon experiments, old and new. He died of heart disease on January 3, 1903.

S. P. T.

MAJOR-GENERAL C. J. B. RIDDELL, R.A. 1817—1903.

Charles James Buchanan Riddell was born at Riddell, Roxburghshire, on November 19, 1817, being the third son of Sir John Buchanan Riddell, Bart., of Riddell, and of Hepple, Northumberland, and of Lady Frances, eldest daughter of Charles, first Earl of Romney. Except for one year at Eton, he was educated at private schools conducted by a clergyman of the name of Heawood.

Early in 1832 he entered the Royal Military Academy at Woolwich, and in the following year gained a prize for mathematics. From the Academy he joined the Royal Artillery as 2nd-Lieutenant on December 19, 1834, thus commencing his military career at the age of seventeen, and it was meet that he should join a scientific corps, for throughout his life his mind was tuned to a strong love of inquiry into the secrets of nature.

In 1835 Riddell was appointed to his first station abroad at Quebec, occupying his time when on leave in visiting the United States and making many friends amongst scientific men at Baltimore, West Point, and elsewhere. Whilst at Washington he was presented to General Jackson, the retiring President of the United States, and also to his successor, President Van Buren. Promoted to 1st-Lieutenant in January, 1837, he returned to England and thence proceeded to Jamaica to join his company in a sailing vessel of 200 tons which took four months to reach her destination. His health breaking down he was invalided to England at the end of 1838.

It was, however, in 1839, when at the instance of the Royal Society and the British Association the first great British attack upon the mysteries of terrestrial magnetism was begun, that Riddell entered upon his public scientific labours. Besides the great Antarctic Expedition under Captain Ross, there were established the four colonial Magnetical and Meteorological Observatories at St. Helena, Cape Town, Hobarton and Toronto.

It was for the post of Superintendent of the observatory at the latter place that as a young lieutenant he was selected by Sir A. Dickson, D.A.G., of the Royal Artillery. To prepare for his work in Canada he was sent to Dublin and there placed under Dr. Lloyd for instruction in the manipulation of the magnetic instruments then in use, as they were of similar kind to those prepared for the colonial observatories.

In 1839 he left for Montreal viâ New York, narrowly escaping shipwreck and still more narrowly the destruction of all the instruments, in the confusion of throwing heavy stores overboard to lighten the ship. His first work was to find a suitable site for the magnetic observatory. Toronto was selected, as Montreal was much affected by local magnetic disturbance, and there he superintended the building of the observatory and mounted his instruments, both magnetical and meteorological. In all this work and in the subsequent conduct of the observations he proved to be both "active and resourceful."

After a year's work, ill health, which so much affected his career through life, obliged him to return to England, leaving the work he had so well established in the hands of Lieutenant Younghusband, R.A.

Sabine, with whom he had kept up a regular correspondence during his time at Toronto, and who duly appreciated his services, suggested and obtained his appointment as Assistant Superintendent of Ordnance Magnetic Observatories at the Royal Military Repository at Woolwich. It was here that the then Major Sabine superintended the reduction and publication of the results obtained at the Colonial Observatories, and with such a devoted and hardworking assistant his labours must have been much lightened. It was here that Riddell carried on for over four years an extensive correspondence with the prominent scientific men of all countries, as well as with the surveying officers of the Royal Navy, on questions connected with terrestrial magnetism and meteorology.

During 1843 he spent three months in Germany, visiting those with whom he had previously corresponded and also in studying the military system of that country, for it must be remembered he was distinctly a soldier, who, besides the science of his profession, had a keen love for other branches of science.

Whilst at the Woolwich Repository an excellent and most useful work was compiled by him, entitled "Magnetical Instruction for the use of Portable Instruments," and printed by order of the Lords Commissioners of the Admiralty in 1844. These instructions remained the established authority for several years, and in 1863 he was invited to revise them, but he was regretfully obliged to decline on account of ill health.

After his severance from his post under Sabine in 1846, Riddell must be remembered principally in his military capacity. He was placed on the Staff at Woolwich, becoming Deputy Assistant Quarter-master-General, and for his services in that post receiving the following encomiums from General Palliser at the close of the Crimean war: "To his untiring energy throughout the late war the successful embarcation of the Artillery without casualty and the provision of all the necessary supplies are to be mainly attributed"; also on "the

great personal exertions of Lieut.-Col. Riddell, whereby the Artillery in the Crimea were provided with very warm clothing and necessaries much earlier than the rest of the army, thus preserving lives and preventing sickness in a very great degree."

On the outbreak of the Indian Mutiny in 1857 he was sent to India, and commanded the siege artillery of Outram's force on the left bank of the Goomtee at the siege and capture of Lucknow in March, 1858. He also commanded the artillery of General Lugard's column at the affair of Tigree, the relief of Azimghar, operations in the jungle and the capture of Jugdespore. He was three times mentioned in despatches, receiving the reward of being made Brevet-Colonel and the Companionship of the Bath. Returning to England on account of ill health in 1863, he ended his active service at Sheerness in 1866, retiring with the rank of Major-General.

His writings on military subjects consisted of papers on the organization of the British artillery and the administration of the British army in 1852, and, when the war broke out in South Africa, papers on the same questions. Being from early life interested in the Education question he wrote several papers on the organization of Church schools.

His life after retirement was chiefly spent in improving his property, a farm at Chudleigh, in Devonshire, and for the benefit of the various philanthropic objects of that neighbourhood, but his interest in scientific progress continued to the last.

In 1847 he married Miss Mary Ross, second daughter of Sir Hew Ross, G.C.B., R.A. She died in 1900, leaving one daughter.

Riddell was elected Fellow of the Royal Society in 1842, and was its senior member at the time of his death, as well as senior officer of the Royal Artillery. Taken ill with influenza followed by pneumonia, he died on January 25, 1903, at Oaklands, Chudleigh.

E. W. C.

FRANCIS CRANMER PENROSE. 1817—1903.

Francis Cranmer Penrose died at Colebyfield, Wimbledon, on February 15, 1903. He was born on October 29, 1817, at Bracebridge, near Lincoln, of which parish his father was Vicar, his mother being a daughter of Dr. Edmund Cartwright, F.R.S. (the inventor of the power loom and wool-combing machine), and authoress of the well-known series of histories published under the assumed name of "Mrs. Markham."

Sent to the Grammar School at Bedford in 1825, he formed what proved a lasting friendship with a schoolfellow, the future Sir Warington Smyth, and in 1829 he was removed to the foundation of Winchester, where he remained until 1835, when, having shown considerable aptitude for architectural drawing, he was apprenticed to the well-known Mr. Edward Blore, under whose guidance he seems to have been thoroughly well grounded in all that pertains to the profession he eventually followed, while still keeping up and extending his taste, already developed, for classical as well as mathematical studies.

In October, 1839, his apprenticeship being over, he went to Cambridge, entering at Magdalene College, where he at once formed a friendship with Charles Kingsley, then an undergraduate at the same College, and with the scarcely less distinguished Charles Blachford Mansfield, then of Clare, and through them with Frederick Denison Maurice, while he fortunately fell under the influence of George Peacock, at that time Lowndean Professor of Astronomy, and also made acquaintance, subsequently to develop into close friendship, with John Couch Adams, whose grand discovery of the planet Neptune had yet to be recognized.

In this way Penrose's attention was directed to astronomical subjects, in the study of which he became so proficient; but he was a man of very wide interests, and devoted himself to boating as a recreation. He was not only Captain of his College boat, which he raised from a low place to nearly the top of the river, but he also pulled an oar in that of the University in the three successive races of 1840, 1841 and 1842, against Oxford; and he was, besides, the inventor of the ingenious method of showing at a glance the varying places of the different boats, which as "boat charts" has become so universally used. He also exercised his physical powers in other ways, as by more than once walking in one day the whole distance between Cambridge and London, skating from Ely to the Wash, and so on.

In January, 1842 (Cayley's year), he graduated as 10th Senior Optime, and immediately after had the good fortune to be appointed to one of the Worts Travelling Bachelorships, tenable for three years, the greater part of which time he spent on the Continent.

There is no need to dwell on his travels at this period, for they have been published in a Memoir by Mr. J. D. Crace, in the "Journal of the Royal Institute of British Architects" (May, 1903). Their bearing was largely on architectural subjects, but Penrose made a great point of acquiring a practical knowledge of modern foreign languages: French, German, Italian, and Modern Greek. For classical Greek he kept up his Winchester knowledge till the end of his life, and would with delight read and recite, to any fit audience, long passages from Homer. In view, however, of his future calling, he worked very hard at sketches or water-colour paintings of the more noted buildings of the countries he visited, to which he added landscape drawing, having taken lessons from so great an artist as Peter de Wint.

In 1846 he accepted a commission from the Society of Dilettanti to take exact measurements of the Parthenon and certain other Greek Temples, and the astounding results of his labours in this respect, proving the wholly unexpected fact that in the finest of those unexcelled works of art there was scarcely a single straight line, was made known in his "Principles of Athenian Architecture," published at the cost of that Society in 1851, of which a second edition was issued in 1888.

On his return to England he pursued the ordinary routine of his profession, but in 1852 he was appointed by Dean Milman Surveyor of the fabric of St. Paul's Cathedral. He entered enthusiastically on the duties of his post, and it was with extreme mortification that some years after he found his suggestions as to the internal decoration of Wren's masterpiece, the principles of which he had studied as closely as those of the Parthenon, set aside by the Dean and Chapter then in power. He found that all influence in regard to this grandest of our national buildings had passed from him, and so he gradually allowed himself to be occupied with other interests, reverting to the archæological researches and the astronomical studies of his earlier days, of which a paper left by him gives a brief account, as follows:—

"After a course of study for professional architecture in London, I went to Cambridge (Magdalene College) and resided from 1839 to 1842, studying chiefly mathematics, but not astronomy in particular. In 1842 I was appointed Travelling Bachelor of the University, and commenced a course of travel with a view to my profession. In this year I resided several months in Paris, and by the kindness of MM. Arago and Laugier was admitted to the Observatory, and had my astronomical instincts much excited by a view of the planet

Saturn on that occasion. But it was not till 1852 that any decided move in that direction took place. I had bought a theodolite, chiefly for use in the accurate measurements of the height of buildings, which I had previously essayed by various approximate methods of triangulation, and on showing this instrument to Dr. G. Boole, Professor of Mathematics to Queen's College, Cork, who happened to pay me a visit, he pointed out to me the interest it would add to what I proposed to do if I turned it also to the heavenly bodies. After this I frequently used it for questions of accurate orientation and time. For instance, the establishment of sun-dials in connection with some of the buildings in which I was professionally engaged gave me occasional opportunities for bringing theory into practice. In 1862 I bought a small astronomical telescope, and four or five years afterwards a larger one ($5\frac{1}{4}$-inch object glass by Steinheil), equatorially mounted by Simms, of London. In 1866 I happened to see an occultation of Saturn by the Moon, in Scotland, for which the predicted time in the Nautical Almanac was not of much use, especially as it was only partially visible at Greenwich, and I endeavoured to obtain, by graphical construction, a more exact correspondence, suited to the site I was then occupying. This first essay was attended with sufficient success to lead me to go into the subject more deeply, and ended in my bringing out a book on the Prediction and Reduction of Occultations and Eclipses (4to, Macmillan, 1869), a book which has been sufficiently sold to run itself out of print, though not enough to invite a new edition.* In 1870 I went to the South of Spain to observe a total eclipse of the sun at Jerez, and was introduced to Professor Young and some other American astronomers who were there established for the occasion. I had proposed to view the eclipse with my smaller telescope ($2\frac{1}{4}$-inch object glass), and to make an eye drawing of the corona, and I placed myself on an eminence in the famous vineyard of Macharnudo. I saw the approach of the Moon over the rapidly-diminishing sickle of sunlight till about one minute before totality, when a cloud intervened, and I had to content myself with the terrestrial effects, which, however, I thought striking enough to repay the trouble I had taken. Eight years afterwards an opportunity presented itself to join an eclipse party, which went to Denver, in Central North America, and I there again met Professor Young, and made several new astronomical acquaintances. Everything was favourable for the observation of this wonderful phenomenon. My report of what I saw has been published in the official United States book, giving an account of that eclipse, July 29, 1878; (Washington Observations, Appendix III, 4to, Washington, 1880). After this I extended

* A second edition was published in 1902.

the graphical treatment which I had applied to the Moon, as above mentioned, to the case of comets, and in December, 1881, read a paper on the subject to the Royal Astronomical Society; but a more detailed article on this subject forms a chapter (Chapter VI) in Mr. G. F. Chambers's Handbook of Astronomy (4th edition, 8vo, 1889). It shows how predictions and reductions, having a very considerable amount of accuracy, may be made by the use of careful diagrams, and involving only a moderate practical knowledge of spherical trigonometry. My last work has been that of obtaining on the spot, by observation of the sun or stars, requisite data, and the application of the formulæ for finding the places of stars at distant epochs, so as to establish a connection between the orientation of Greek temples with certain stars which at some period (assumed to be the time of their foundation) were coincident at their rising or setting with the direction of the axes of the temples under consideration. The rates of apparent movement in the stars, owing to the precession of the equinoxes, giving dates for the foundation of the temples, on the theory that they then coincided, as above remarked. It is presumed that the object sought by the ancients in so orienting their temples was to obtain from the stars at their rising or setting, as the case might be, a sufficient warning of the approach of dawn for preparation for the critical moment of sunrise, when the sacrifices were to be offered."

The concluding paragraph of the above statement refers to the fact that, after Sir J. Norman Lockyer had suggested the possibility of estimating the age of some of the Egyptian temples from the direction of their axis, as explained in the "Proceedings of the Royal Society," Mr. Penrose undertook the examination of many of the Greek temples from the same point of view, the results of which, confirming the suggestion, and explaining what may be called the principle of orientation observed in the erection of many later edifices, were published in the same "Proceedings," as well as in the "Philosophical Transactions"; his latest work on this subject having been executed in conjunction with Sir J. Norman Lockyer in regard to Stonehenge, which, having been found by careful observation to have been erected on the same principles as the Egyptian and Greek temples, enabled a date to be approximately assigned to it.

Mr. Penrose's publications were not numerous; besides his classical work on the Parthenon, that on the Prediction of Occultations in this place chiefly demands notice, but it must not be omitted that he was the author of the article on Sir Christopher Wren in the "Dictionary of National Biography." He was elected a Fellow of the Royal Society in 1892, and in 1898 received the honorary degree of Doctor of Letters from the University of Cambridge, and the Doctorate of Civil Law of Oxford. He was also President of the Royal Institution of

British Architects from 1894 to 1896, and Antiquary to the Royal Academy. His old College, on the alteration of its Statutes admitting the election of Honorary Fellows, took the first opportunity of electing him one of them.

A remarkable portrait of him, painted by Mr. Sargent, R.A., is in the possession of the R.I.B.A., and a copy hangs in his own College at Cambridge.

F. G. P.

CARL GEGENBAUR. 1826—1903.

Carl Gegenbaur was born at Würzburg, Bavaria, on August 21st, 1826. Having passed through the classical school or gymnasium of his native town, he, in 1845, matriculated at the University of the same place as a student of medicine and natural sciences, and profited of the influence of such celebrated teachers as Kölliker, Virchow, Leydig, and H. Müller. A clear proof of his preference of zoological anatomical research, instead of the practice of medicine, is the subject of his dissertation for the degree of M.D. (1851), "De Limacis Evolutione," and the theme of his subsequent public oration, which dealt with "The Variability of Organisms." The young doctor, fortunately of independent means, soon found his way to Johannes Müller, in Berlin, with whom, however, he stopped but a short time before he went with H. Müller and Kölliker to Messina. Altogether he travelled in Sicily, observing, sketching and collecting, for nearly two years, and then he returned to Würzburg, where, in the spring of 1854, he "habilitated" as *privat-docent*, the subject of his inaugural dissertation being the "Alternation of Generations and the Propagation of Medusæ and Polyps." In the autumn of 1855 he accepted the post of Professor extraordinarius at Jena for Zoology and kindred subjects, and three years later, after the death of Huschke, he took the newly-reorganised Chair of Anatomy, with which he continued to combine the teaching of Zoology, until, in 1862, he handed the latter over to Häckel, whom he had advised to come to the quiet Thuringian seat of learning and research. The friendship between these two great men became intimate and lasting.

Jena was then fast becoming a famous centre of medical and biological sciences. A considerable number of the professorial staff

were men of fame, and a school of new men sprang up, who have made their mark; but, above all, it was Gegenbaur himself who, during the fourteen years which he spent at Jena, added to its fame. Various Universities, in Germany, Austria and Holland, had tried to attract him. Heidelberg succeeded in the autumn of 1873, Gegenbaur becoming the successor of F. Arnold, his father-in-law. He remained there to the end, to become one of the brightest stars in the diadem of the Alma Mater Leopoldina-Carolina.

Much trouble was implied in the adjustment of the practically new Chair of Anatomy. Administrative duties in the University, later on, also, his position as a Councillor of State, in addition to his normal professorial work, and last, not least, his original researches, required an enormous amount of labour, which could be mastered only by his robust constitution, iron will, and almost entire abstinence from social intercourse. As a rule he enjoyed excellent health—only once, but then seriously, interrupted by a severe and protracted illness in 1881, after which he "felt better and more vigorous than ever." Towards the close of the century he aged rapidly. He resigned his chair and all his work in the spring of 1901, suffering much from creeping paralysis, and he died on the 14th of June, 1903, in his 77th year.

The outward signs of the appreciation of Gegenbaur's work were many, in the shape of honorary doctor-diplomas, medals, decorations (*e.g.*, Pour le mérite), the position of Councillor of State of the Grand Duchy of Baden, and many others. On the occasion of his 70th birthday many of his former pupils presented him with a "Testschrift" of three big volumes. The Royal Society elected him a Foreign Member in 1884, and awarded him the Copley Medal in 1896 for his "pre-eminence in the science of comparative anatomy or animal morphology."

Gegenbaur's "Wanderjahre," and even the first five years in Jena, were devoted, almost without exception, to the invertebrata, concerning which he published some thirty papers, dealing chiefly with cœlenterates, echinoderms, molluscs, and tunicates. In 1859 appeared his "Grundzüge der vergleichenden Anatomie," a comprehensive work on the whole animal kingdom. Then came the turning point in the direction of his studies, marked by the editing of H. Rathke's lecture notes on the comparative anatomy of vertebrates. The observations and views of this excellent and careful morphologist had a lasting influence upon Gegenbaur, who ever since, until the end, devoted all his boundless energy to the study of the vertebrates, without, however, losing touch of the invertebrates. On the contrary, he always used them as a kind of prolegomena for the elucidation of the organisation of the higher phylum.

This is not the place for the enumeration of his researches, which

comprise every organic system (about eighty papers and separate publications), the egg, the processes of ossification, etc. Only some of his epoch-making works can here be dealt with. Such are, for instance, his "Untersuchungen zur vergleichenden Anatomie der Wirbelthiere," Carpus and Tarsus, 1864; "Shoulder-girdle and pectoral fins," 1865; and "Cranial skeleton," 1872. The entirely new and evolutionary treatment of these problems at once attracted universal attention.

His "Grundzüge" were written in pre-Darwinian times. A second edition, practically re-written and considerably enlarged, was based upon the theory of descent, and inaugurated a new era, 1870. Further editions, much condensed and amended, appeared under the title of "Grundriss" in 1874 and 1878. Like its predecessors, this work dealt with the whole animal kingdom. Officially, be it remembered, Gegenbaur filled the Chair of Human Anatomy, which, as usual, implied the direction of the much-frequented dissecting classes. "Picture books" and topographical anatomy were not in his line, but in 1883 he surprised the world with a text-book of human anatomy, which likewise marked a new epoch, because, for the first time, the nomenclature and the general treatment of human anatomy were put upon a firm comparative anatomical basis. That such a book was wanted is proved by the unparalleled fact that by the year 1898 it had reached its seventh edition, which comprises more than 1,100 pages, with some 700 text illustrations. Although this book is a priceless boon to those who want to infuse scientific life into the study of anthropotomy, it is, perhaps, to be regretted that the great amount of time implied in its production, with its ever-improved and enlarged editions, was not instead devoted to the crowning work or coping-stone of Gegenbaur's genius, the "Vergleichende Anatomie der Wirbelthiere, mit Berücksichtigung der Wirbellosen," the first volume of which appeared in 1898, the second, and last, in 1901.

In broadness of plan, depth of conception, critical execution, and as a mine of wealth in most suggestive ideas, it cannot be surpassed. But what was the method by which Gegenbaur attained his highest standard? The truly comparative method, based upon the knowledge that it is the function which makes and modifies organs, that such acquisitions are inherited, and that no deductive reconstructions of an ancestral stage are acceptable unless they stand the test of physiological continuity. The axiom, "Ex nihilo nihil fit," and the search for sufficient "causal moments," must be the leading principles, lest our evolutionary disquisitions become nothing but more or less veiled teleological paraphrases. Of the latter fault, he, often with ironical vehemence, accused the "embryographers," the champions of the purely ontogenetic method.

Lastly, a few remarks about the man. Tall, robust, with upright

gait, and of the dark Bavarian type, with the powerful head and strong neck upon broad shoulders, steady searching brown eyes, his was an imposing appearance. Absolutely straightforward and reliable, stern, terse and direct of speech, matter-of-fact and somewhat choleric in temperament, he was difficult of approach. Attempts to interview him for the mere sake of self-gratification invariably led to most disconcerting results. As he hardly uttered a sentence unless it was pregnant with criticism or advice, he at least expected absolute concentration, plain statement, and logical concatenation of facts. The slightest slip in thought or expression was pulled up with a sharpness often distressing. His intuitive power of reading the character of his pupils either made their existence a burden or life worth living. Every day he paid a visit to those who were engaged in private research. The greater the difficulty, the kinder and more encouraging he became, and the resulting discussions, by which he opened up new vistas, criticising the methods and results of other workers, were perhaps the most precious occasions for those who had come to the master for the sake of learning how to research. "I approve of your problem, but don't imagine that I am going to help you. When you have got into it, we shall have something to talk about." Nor did he trouble about the technique.

His influence as a teacher was great because of his clearness and his power of treating the theme of his lecture in the shortest compass. As a speaker, he was not brilliant; on the contrary, his delivery was often laboured, hesitating for the right word, but then that particular sentence was complete and formed an integral part of the whole, and this carried conviction.

No wonder that all, Germans and foreigners alike, who succeeded in seeing more of the man, felt his magic influence and learnt to admire him, while those who had the privilege of more personal intercourse with their master came to look up to him with a gratitude and reverence bordering on veneration. Of course, he also made enemies, chiefly through his merciless criticism, and they have not been slow in blaming his followers for being too prone to accept his theories as so many cases of *αὐτός ἔφα*. No doubt he too has erred. Nevertheless, Gegenbaur is not only the founder of modern comparative anatomy, but he has raised the building to a great extent by his own hands, supported by a school of disciples, steadily increasing through his stimulating and correcting influence. The man is gone, his works remain, and through them his method.

H. F. G.

ANDREW AINSLIE COMMON. 1841—1903.

Andrew Ainslie Common was born at Newcastle on August 7, 1841. He showed an interest in astronomy very early, for his brother, writing of a time previous to 1851, remembers that "he was always at the telescope" (an instrument which his mother had borrowed from Dr. Bates, of Morpeth). . . . . "Whenever I missed him I ran into the house and found him at the telescope." Owing to ill-health first, and afterwards to the necessity for taking up business, his astronomical enthusiasm lay dormant for some years after this, but in 1874 he had a $5\frac{1}{2}$-inch refractor mounted equatorially in a dome in London. Afterwards he moved to Ealing, where he lived till his death; he set up larger instruments, joined the Royal Astronomical Society in 1876, and from about that time, in spite of the claims of an active business life, continued to work successfully at his favourite science, and to be a prominent figure in astronomical circles.

The earliest work of which there is any published record was on the satellites of Saturn and Mars ("Mon. Not. R.A.S.," vol. 38, p. 97), and characteristically included an improved method of getting position-angles. Common was seldom content until he had suggested some essential improvement on previous methods. There is a hint, too, of dissatisfaction with the power of his instrument (an 18-inch speculum, by Calver, which would have satisfied most of the amateurs of the day), since the inner satellite of Mars could not be seen; and in this we may trace the determination, already formed, to have the larger instruments which made Common famous. Little more than a year afterwards he published his ideas on the subject of large telescopes, and it is noteworthy that his opinion was courageously at variance with that of one of the first instrument makers of the day ("Mon. Not. R.A.S.," vol. 39, p. 383, footnote). He proceeded to order the well-known 3-foot mirror from Mr. Calver, the mounting being his own design, and this instrument was a great success. He could now see all the satellites of Mars and Saturn easily, and corrected an error of about one and a-half hours in the ephemeris of Mimas, which had remained undetected for some time, and had been the cause of some curious records by other observers. But an even greater success was in store; he turned his attention to photography, and took the first successful photograph of a nebula—the great nebula in Orion. For this he received the gold medal of the Royal Astronomical Society in 1884. In presenting to the Society a

carbon enlargement of this picture (taken on January 30, 1883, with 37 minutes' exposure), he modestly remarked of it that "although some of the finer details are lost in the enlargement, sufficient remains to show that we are approaching a time when photography will give us the means of recording, in its own inimitable way, the shape of a nebula and the relative brightness of the different parts in a better manner than the most careful hand-drawings." He might well have said that the time was already come, for the chief steps had certainly been taken, and we may note with admiration that they had been taken by a man who had only been able to devote himself to astronomy seriously during the leisure of some half-dozen years. In that brief period Common had realised the limitations of an 18-inch telescope, which may be taken to represent the best instrument available at the time for a man of moderate means; had determined on the bold experiment of doubling the diameter, and carried out the project successfully; and had assigned to the reflector that work of photographing the nebulæ which has come to be regarded as its chief function. All this was not done without much hard work, and it is not surprising if the pace was not maintained afterwards. An opportunity occurred for selling the 3-foot telescope, and Common then deliberately took a complete year's rest before commencing another astronomical enterprise; though during this period the project of making a much larger telescope still (mirror 5 feet in diameter) was already in his mind, and plans were maturing. He had indeed, so early as 1880, determined to have this telescope, and to make it entirely himself, and had ordered a disc of glass for the purpose, but the instrument was not completed till 1891. A full account of its construction is given in "Mem. R.A.S.," vol. 50, and he was able to announce that "the power of the 5-foot over that of the 18-inch and 3-foot is proportionate to the size. On nebulæ this is seen to great advantage, both visually and photographically. Such an object as *Mimas*, which the 18-inch telescope would, under the most favourable conditions, just render visible, and the 3-foot show fairly well, can with the 5-foot be seen close to the end of the ring, and away from it could not be overlooked." But this satisfactory result was not attained without encountering many difficulties. Of one grinding tool that he tried he reports:—"The tool was several months in preparation, but a very few minutes' work sufficed to show that it was unworkable. The faces of the glass squares caught the mirror and tore it up in places, but where this had not occurred the surface produced by grinding glass on glass was all that could be desired." Such failures might have discouraged a less resolute man, but Common simply utilised them as lessons of great value, and seemed actually to rejoice in them. "I consider it an extremely fortunate circumstance," he writes, "that the first mirror

gave such a very bad image that it had to be condemned, and another disc of glass made. Had it been just passably good, it is more than probable that I should not have made another, but should have come to the conclusion that the limit of useful size had been reached." He is here speaking of the loss of two years' work, during which more than two million strokes had been made with the grinding tools, and, as he admits in another chapter, "the greater part of the period was a time of worry and anxiety." But when he realised that it was labour lost and he must begin afresh, he merely dwells with satisfaction on the nett result—that from the experience gained he was able "to make the second disc into an almost perfect mirror in three months."

Unfortunately the telescope, though completed, has not been much used. Some excellent photographs of nebulæ were taken with it, and only withheld from publication because Common felt he could improve upon them. But while using it one night he narrowly escaped falling from the high staging necessary to work a Newtonian reflector—such a fall would certainly have been fatal—and he resolved that he must not run a similar risk again. Consequently he decided that the telescope must be re-arranged on the Cassegrain plan, so that the observer might work in safety from the floor, and some years were spent in experiments on the best method of doing this. Cassegrain's actual design involves a central hole in the large mirror, and there were known difficulties in the way. At first an attempt was made to alter the plan to an "oblique Cassegrain," leaving the mirror intact; and promising results were obtained, which, however, never got beyond a certain limit. Accordingly the known difficulties of making a central hole were attacked and conquered, and a successful mirror produced, so that the telescope is complete either as a Cassegrain or a Newtonian.

About this time, however, Common's attention was diverted to problems concerning gun-sights and telescopes for the army, and this was work which specially suited and attracted him. All observations with the 5-foot came to a standstill, and he realised that he was unlikely to resume them. An additional discouragement arose from the deterioration in the atmospheric conditions, which proceeds inexorably in the neighbourhood of London. Common felt that to do the instrument justice it ought to be transported to a good climate, and though plans for doing this were often vaguely in his mind, he never crystallized them. His sudden death leaves standing in a suburban garden, unused, what is probably the finest telescope in the world.

In the ordinary course of business Common had acquired considerable engineering knowledge, which helped him materially in the

construction of his instruments. Many of his scientific papers contain suggestions of great value for the improvement of instruments. Thus he pointed out that when taking a photograph with a large telescope any small defects of clock-driving should be corrected, not by moving the whole telescope, which will introduce strains and set up oscillations, but by moving the plate alone.

He suggested that the heavy parts of big instruments should be floated, and carried out the idea beautifully in the case of his 5-foot. There is a paper of his ("Mon. Not. R.A.S.," vol. 44, p. 288) on "Improvements in the construction of large transit circles," which has attracted little attention, but which contains several suggestions of obvious value and importance.

He was thoroughly appreciative of the work of others, especially when it lay in fields familiar to him. Lord Rosse's work on the nebulæ was constantly referred to by Common in terms of warm admiration; when he presented his successful photograph of the Orion nebula to the Royal Astronomical Society, as above mentioned, he characteristically took the opportunity of referring to Lord Rosse with enthusiasm. Foucault, who had developed the plan for testing mirrors, was another of Common's heroes. And his was no mere idle appreciation—he carried it to a practical issue by carefully studying what others had done before he commenced his own operations. "A plan of work was sketched out," he writes in the introduction to his account of the making of the 5-foot, "in which an endeavour was made to adopt, as far as circumstances permitted, all the essential things that had been pointed out by previous workers." At the same time, he was too courageous to be fettered by the opinion or practice of his predecessors, however impressively unanimous. "Every well-known worker hitherto, without exception, has begun by making small mirrors, and, as experience and skill were gained, has increased the size of the discs." The weight of testimony was treated by Common with respect, but ultimately disregarded when there seemed to be good reason for a more enterprising course.

The skill acquired in the difficult art of grinding mirrors was used for the general good with unstinting generosity. Common made a large number of mirrors at different times, which were presented to colleagues, or put at their disposal for the minimum cost. He made not only concave but plane reflectors, such as those required for cœlostats used on British eclipse expeditions. Indeed, his help with these instruments at a critical time was undoubtedly the means of introducing them to the attention of astronomers, who have since learnt more of their great value. Two concave mirrors of 20 inches aperture and 45 inches focus, made for eclipse work and used in 1889, are also well worthy of special mention.

He was much interested in eclipse work, and took a prominent part in the organisation of the different Committees which ultimately merged in the present Joint Permanent Eclipse Committee. He himself went on the expedition to Norway in 1896, arranging a very complete plan of operations for the party he took with him, but clouds prevented them obtaining any results.

As an observer, he was quick to seize the suggestions of experience. The discovery of a comet at the total solar eclipse of May 16, 1882, suggested to him to search the neighbourhood of the sun for bright comets, which he did for some time assiduously, and he was rewarded on September 17 of the same year by the independent discovery of the great comet of 1882 (see *Observatory*, vol. 5, p. 319, and *Astr. Nachr.*, vol. 103, p. 159). He was thus the first to see it in Europe, although the comet had been previously noticed from the Southern Hemisphere.

He took a prominent part in the Conferences which organized the Astrographic Chart, and although he had himself shown how much could be done with reflecting telescopes, he unhesitatingly and impartially advised the adoption of the refractor as the proper instrument in this case, recognising the beauty of the results obtained by the Brothers Henry. He knew not only the merits but the imperfections of the reflector; it had vagaries which not every man had the patience to learn, and it could not be recommended for indiscriminate use. He used to quote with approval the example of Lassell, who broke up his big reflector rather than let it pass into unappreciative hands. But given patience and skill on the part of the observer, such as Common possessed, the reflector can out-distance its competitor, and Common's name must be added to that illustrious list of English names—Newton, Herschel, Lassell, De la Rue—associated with the demonstration of this fact. Indirectly, too, he had some share in transplanting the instrument across the Atlantic, where it promises to thrive even more prosperously than in the old country.

A few words may be added concerning the work on gun-sights for the army and navy, which was occupying his attention in the last years of his life. Although in some ways of a technical character, it required scientific skill of a high order, and was of national importance. Some of his devices were exhibited and admired at the Conversaziones of this Society in 1903 (at the first of them he was himself present, but his death had occurred before the second); but he felt that there was still much to be done, and looked forward with confidence to doing it. As regards its national importance the following words of Captain Percy Scott, R.N., spoken at a dinner at the Savage Club on November 22, 1902, may be put on record here. He said, "that the nation owed a deep debt of gratitude to Dr. Common for the great improvements that he had made in gun-sights. It mattered not how good the gun was, nor how good a

man there was behind it; unless the sight was perfect, good firing could not be made. The great stride made by the British Navy lately in that direction was entirely due to Dr. Common. He had combined the great knowledge of optics, which had made him a Fellow of the Royal Society, with practical application, and produced a telescope gun-sight which would, when properly used, quadruple the fighting efficiency of our battleships."

Common was elected a Fellow of this Society in 1885, and served on its Council in the years 1893–5. He was Treasurer of the Royal Astronomical Society from 1884 to 1895, when he was made President. He received the Honorary degree of LL.D. from the University of St. Andrews in 1892.

He died very suddenly on the morning of June 2, 1903, from heart failure, while sitting writing in his study at 63, Eaton Rise, Ealing. He leaves a widow, one son, and three daughters.

H. H. T.

Salisbury

Photo by J. Phillips, Belfast. *Swan Electric Engraving Co.*

OBITUARY NOTICES

OF

FELLOWS DECEASED.

(Part iv.)

THE MARQUESS OF SALISBURY, K.G. 1830—1903.

Robert Arthur Talbot Gascoyne-Cecil, the third Marquess of Salisbury, was born on February 3, 1830. He succeeded to the title in 1868, and died on August 22, 1903.

Lord Salisbury was elected a Fellow of the Royal Society in 1869; he served on the Council in 1869–1870, again in 1882–1883, and for a third time in 1892–1894; he was a Vice-President in 1882–1883 and in 1893–1894. By his death the Royal Society has lost a Fellow who combined genuine scientific instinct and interests with a unique position as a statesman whose advice and co-operation have therefore on many occasions been of the greatest value.

Lord Salisbury was generally known to take great interest in physical science, and he spent much of his spare time in experiments. He experienced some of the vicissitudes incident to chemical experimenters, having once been nearly suffocated by inhaling chlorine, on another occasion having had a bad explosion with sodium. His fondness for botany placed him, on one excursion, in a novel situation; while searching for plants on a neighbouring estate, the keeper mistook him for a poacher. Although he published very little, he took careful notes of his work. These records have not been found, with the exception of three small note-books, containing disjointed entries from which only an imperfect idea of the work can be obtained. Though he often talked in private about scientific subjects, his well-known dislike of egotism prevented him from referring to his own performances.

He seems to have been much attracted by photography at an early period. In 1864 he wrote an article on that subject for the "Quarterly Review," which was published in the October number, pp. 482–519.

This appeared as a review of 'A Manual of Photographic Chemistry,' by T. Hardwick, and of a book on 'The Tannin Process,' by C. Russell. It is written in his characteristic style, and gives a good account of the condition of photography at that period, when dry plates were first suggested and discussions were proceeding between artists and photographers. In one of the note-books above mentioned is a list of photographic and chemical apparatus dated December, 1865.

About 1869 he was experimenting with magnetism, and had a large electro-magnet constructed with the intention of investigating the rotation of the plane of polarisation of light in the magnetic field. Later he experimented on the determination of the law of variation of magnetic action with distance, by measuring the throw of a galvanometer needle due to the current induced in a coil with a soft iron core, when it was placed at different distances from another similar coil through which an electric current was passed.

In 1872 Lord Salisbury noticed the illumination in the vacuum in the tube of a thermometer placed near an induction coil in action. The following extract relating to similar phenomena, copied, by permission, from a note-book belonging to the latter part of the year 1872, from which the first pages are missing, will convey a good idea of his mode of working, whilst it is also of intrinsic scientific interest.

"Connect one pole of a strong induction coil with the outside of a large thoroughly insulated jar. Take the cap off the jar; inside of it hang a Geissler tube three inches from the bottom. Let it be hung by a wire connected to earth; the other pole may be connected to earth or not connected at all. If the positive current is taken to the jar no apparent discharge, silent or other, will pass from jar to tube; but the tube will lighten. If the negative be taken to jar, a brush will appear at the end of the tube. Break contact. Take out the tube, carefully avoiding to touch the inside of the jar. Then, holding tube, pass it with a quick motion up and down through the mouth of the jar, but never touching; at each passage up and down the tube will lighten. This may be done for an indefinite number of times, and the light in the tube will strengthen rather than fall off. The tube may be laid aside for half-an-hour, and at the end it will still lighten; but the effect is slighter. For this experiment tube and jar must be dry, the insulation of the jar must be very good, and the discharge must be strong.

"This action bears a strong analogy to the action of a closed circuit moved in front of a magnet. The tube is practically a closed circuit, for except in air artificially dried all circuits are so to intense electricity. It is worthy of note that no light is seen unless the tube is taken completely out of the jar at each other stroke.

"If instead of the jar a sheet of copper, insulated between two india rubber pads, be used, the same effect may be produced in a slighter degree. Also, if instead of an india rubber pad, a long coil of insulated wire, in a flat case, be laid on the copper, after contact broken, if the tube be passed sharply across the coil lengthways—not touching, but very close—light will be produced at each stroke for a little time. The difference in effect probably results from the fact that a jar is a form capable of more insulation than any other.

"If the poles of a strong coil be one connected to earth through a jar—or with considerable interval—the other not at all—the whole surrounding space near the jar and the coil, or anything in connection with either, will be in a state of excitement. The tube, if held any way in the air will show it, but most if held normally. A thermometer will show it, giving a mercury light. The thermometer will show it, even if enclosed in an upright tall narrow jar (dry). If a coil so arranged is in action, and an india rubber disc be laid on the table not far from the jar, and a tube be laid upon it, the action can be so regulated that the tube will be just short of lightening. Put the finger near it in any direction, and the part of the tube nearest the finger will lighten. If a thermometer, standing as above described, be grasped by the finger and thumb, the part grasped will have a thicker and stronger light than the rest of the tube.

"Hang the tube over a plate of copper in connection with one pole; the other pole to earth; tube to earth. Approach the tube (using negative to plate) till there is a brush discharge from tube, with occasional sparks. Let tube be a hydrogen tube. Examine the light in its strongest part by spectroscope. As long as the brush discharge is going on it is a mercury light (?); but when the spark comes, C and F shoot across the spectrum."

In further experiments a bell-jar was placed on the plate of an air pump and exhausted; over it was inverted a Leyden jar from which the interior connecting rod had been removed, and the outside of the jar and the air pump plate were connected to the coil; a brilliant discharge was found to be produced in the bell-jar when the coil was in action. When the coil was stopped, and the wire attached to the Leyden jar was removed, occasional glimmers were seen in the bell-jar, which lasted for some time and were renewed on touching the jar with the finger. This experiment was modified by charging a Leyden jar by an electric machine, removing the interior connecting rod and inverting the jar over a small bell jar on the air pump plate, the edge of the jar resting on the plate. A flickering discharge, which was called "summer lightning," was seen, and lasted for some time, and was renewed on touching the outside of the jar, from which a small spark was drawn. An exhausted and sealed tube, without electrodes,

became luminous on plunging it into a charged jar, and also on withdrawing it.

In the same note-book from which quotations have been made above there are recorded detailed observations on the spectra shown in thermometer tubes, made at various dates up to February 25, 1873. These latter formed the subject of a short paper in the "Philosophical Magazine" for April, 1873 (4th series, vol. 45, pp. 241–245), entitled 'On Spectral Lines of Low Temperature,' which passes from observation to theory. It would appear that in writing this paper Lord Salisbury had regarded the phenomena described as more dependent on conduction than, in the light of modern experience of electric oscillations, we could now admit; while the changes in the spectra are discussed on the supposition that they are controlled by the temperature of the residual gas. The absence of the hydrogen spectrum he believed to be due to the low temperature of the discharge.* He set about determining this temperature. Experiments with a vacuum tube without electrodes, and having the bulb of a small air thermometer sealed into it, gave some indication of increased temperature when the discharge passed through the tube.

In consequence of a brush discharge being observed at the top of the thermometer, it was apparently thought that the illumination of the thermometer was accompanied by conduction through the glass. An experiment was made subsequently in which an exhausted tube, five feet long, and without electrodes, but with the ends covered with tin foil, was placed with one end in contact with the prime conductor of an electrical machine. On working the machine the tube was illuminated until the charge became constant, and on discharging the conductor a flash was again seen in the tube. With a Holtz machine, having the electrodes near together, so that frequent discharges occurred, the tube was brilliantly luminous when one end was placed in contact with one of the electrodes, the other end of the tube being insulated. If a brass ball connected with earth was placed near the tin foil covering of the distant end of the tube, sparks passed at each discharge of the Holtz machine. This tube, made in July, 1874, is an early example of the electrostatical variety of electrodeless vacuum tubes. From letters by Mr. J. T. Bottomley in "Nature," vol. 23, 1881, pp. 218 and 243, it appears that Sir W. Thomson and he had independently observed the same phenomena.

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* H. Keyser, "Handbuch der Spectroscopie," vol. i., § 204, mentions these experiments of Lord Salisbury as the first in point of time in which the conclusion was drawn that a gas at low temperature can emit a bright spectrum.

When using thermometers in the above experiments, they were found to be very frequently pierced by the discharge at the sealed point. This appeared to be due to the pointed form of the interior space. A piece of glass tube was heated in the blowpipe and drawn out, forming two closed tubes; the closed ends were then fused together and slightly drawn out so that they were connected by a rod of glass, the interior spaces of the tubes being pointed. When the electrodes of the coil were inserted into the open ends of the tubes, and the coil set in action, the intervening glass was pierced in less than three minutes. A vacuum tube, with one end drawn out to a fine point and sealed, was instantly pierced when the pointed end was rested on the metallic plate connected to one pole of the induction coil. Lord Salisbury observed that india rubber when exposed to light undergoes a change, and a casual remark of his led to the experiments described in a letter to "Nature," vol. 27, 1883, p. 312.

Arc lamps worked by primary batteries were used at Hatfield as early as the winter of 1869–1870 to illuminate the south front of the house on the occasion of the County Ball, and from 1879 to 1881 experiments were made on the lighting of the interior of the house by electricity. At first the dynamos were placed in or near the house and worked by a steam or gas engine. Afterwards the machines were placed at the saw mills at a distance of more than a mile from the house, where they were actuated by a water-wheel on the River Lea, which runs through the park; subsequently a turbine was used. Hatfield House was one of the first large houses in the country to be lighted by electricity. Electric motors were afterwards used in some farming operations, especially for cutting weeds in the river.

In 1881 and 1882 numerous experiments were made to obtain two pieces of the same metal that would not produce an electric current, when they were dipped in water and connected through a galvanometer. The experiments were first made with two sovereigns with pieces of wet paper between them; on connecting the coins to a galvanometer a current was always detected. Platinum wires and rods were next tried, and notwithstanding their being cut from the same piece of metal and being cleansed by action of many different substances and by heating, it was not found possible to obtain them in identical states. Two wires were heated by an electric current in an exhausted tube, to which a side tube containing dilute sulphuric acid was sealed, with the expectation of removing occluded gases; but a powerful current was produced when the tube was inverted so as to connect the wires by the dilute acid. Very little regularity was observed in the direction of these currents; but at last it was found that if a wire were left for some time in a solution of a permanganate, washed

with water and dried with filter paper, and then plunged into a test tube of water in which another platinum wire was immersed, a current was produced; while if the wire were removed, left for some time in a solution of pyrogallic acid, washed and dried as before, it produced a current in the opposite direction when again introduced into the test tube. A platinum rod was suspended for a short time in the mouth of an ammonia bottle without touching the neck, washed in a bowl of water and wiped with filter paper, and it then produced a current in one direction when placed in a vessel of water in which a similar rod was lying; if the rod was exposed to the fumes of nitric acid and treated in a similar manner, an opposite current resulted. When wires immersed in dilute acid exactly compensated each other, mechanical disturbance of one of them, of the nature of bending or stretching, caused an immediate indication of current in the galvanometer.

In 1883 experiments were made with the flame produced between the secondary terminals of a coil when the primary was in circuit with a Siemens alternating dynamo. The spectrum of the flame was examined, and also the spectra produced when salts of metals were introduced into it. These experiments were subsequent to those of Mr. Spottiswoode.

When Lord Salisbury was Secretary of State for India he forwarded a despatch to the Governor-General, dated September 28, 1877, enclosing a memorandum from Mr. Lockyer recommending the establishment of a station in Northern India for taking daily photographs of the sun. Lord Salisbury warmly supported the recommendation, and, in consequence of his action, photographs of the sun's disc have been taken daily, with few intervals, up to the present time. The correspondence on this subject will be found in the Reports of the Committee on Solar Physics. Lord Salisbury showed his personal interest in the subject by paying frequent visits to Mr. Lockyer's laboratory while the work on the spectrum of hydrogen was in progress.

In 1894 Lord Salisbury presided over the meeting of the British Association at Oxford. In his opening address, which attracted much attention at home and abroad from its wide range of knowledge, and is still vividly remembered, he insisted that we are in a condition of uncertainty in many fundamental problems of science, and that many of our general conceptions necessarily remain incomplete and tentative.

The foregoing is, in the words of one who knew him intimately, "a record of work done in the spare moments of a man whose thoughts as well as his time were claimed by very much besides. Slight as it is, there is enough to suggest that if the power of continuous concentrated thought, which was peculiarly his characteristic, had been devoted

to science, he might have achieved something considerable. He was an amateur in nothing—in the sense, that is, of giving half his thoughts to it. Whatever he worked at absorbed him entirely for the time, and that was doubtless the reason why during the last eighteen years of his life public affairs left no room for scientific activity."

H. McL.

ALFRED RICHARD CECIL SELWYN. 1824—1902.

The subject of this notice had a unique experience of official scientific life, having served, with a practically continuous career of about half-a-century, on three Geological Surveys, and having been at the head of two of them. Beginning at home, his survey-life was shifted eastward and westward to distant colonies, as shown below:—

Geological Survey of England and Wales, 1845 to 1852, about 7 years.

Geological Survey of Victoria (Director), 1852 to 1869, about 17 years.

Geological Survey of Canada (Director), 1869 to 1894, about 25 years.

He was the son of the Rev. Canon Townsend Selwyn, and his wife, Charlotte Sophia, daughter of Lord George Murray, Bishop of St. David's. He was born July 28, 1824, at Kilmington, Somersetshire. He married, in 1852, Matilda Charlotte, daughter of the Rev. Edward Selwyn. On all sides, therefore, he was connected with the church, of which another member of his family, Bishop Selwyn, was a conspicuous officer. Nevertheless, he did not have a University education; but was at first brought up at home and afterwards in Switzerland, in which country he got his first taste for geology.

Selwyn joined the English Geological Survey at the age of 21, under Sir H. De la Beche, and had the good fortune to have Ramsay as his teacher in geologic mapping in North Wales. His ability for this work was soon shown, and for some years he took a prominent part in the difficult task of mapping the Palæozoic rocks of that district and its borderland, a task in which his powers as a climber greatly aided him: indeed for this reason much of the toughest work, from an athletic point of view, fell to his share.

Amongst other things, he mapped the complicated volcanic district of Cader Idris, and was the first to discover an unconformity between

the lowest Cambrian rocks and the older schists beneath, a view however which, in those early days, was not accepted by his colleagues, excepting, perhaps, De la Beche. He also did some survey-work on less ancient formations in Shropshire.

He had a share in no less than sixteen of the Geological Survey Maps, some of which are of a very detailed character, and, indeed, are monuments of early mapping; also in six sheets of Sections, across difficult country.

Sir A. Ramsay did not fail to acknowledge the excellence of Selwyn's work, and with another genial member of the staff, J. B. Jukes, a great friendship was also formed.

Passing to the colonial work, in which the greater part of his life was spent, on getting to Victoria, Selwyn soon undertook the investigation of gold-bearing rocks and gravels, and prepared various reports and papers on the economic geology of the colony.

Unfortunately, however, this valuable work came to an end in 1869, when the legislature, with short-sighted economy, refused to grant the funds that were needful for the continued progress of the Survey. But Selwyn's services were secured by another colony, which has had the honour of keeping up a highly efficient Geological Survey for many years, a survey which has enriched geologic knowledge and advanced its practical applications in a marked degree, very largely through Selwyn's able guidance.

It is indeed in connection with the Geological Survey of Canada that Selwyn will be best remembered, as he spent a quarter of a century of his official life as its Director, an appointment made on the recommendation of the retiring chief, Sir W. Logan, whose earlier work was done in South Wales, as Selwyn's was in North Wales.

Selwyn began his duties in Canada at a time when the confederation of some of the provinces of that great colony had but just been carried out. In consequence of that confederation, the area of Canada, and therefore the sphere of the Geological Survey work, considerably increased.

Here, as in Victoria, he strove to advance geology from the practical and economic side, as well as from what is termed the purely scientific side, making many investigations and explorations that were of great practical value. Indeed Selwyn may be instanced as one of those broad-viewed geologists who realised that a Government Survey is not established simply for the exploitation of difficult scientific problems (some of which may be beyond the reach of most of those observers who take up geology as a highly enjoyable pursuit), but also for the careful recording of facts and for bringing those facts to bear on questions of public utility. He tried to make the Canadian Geological

Survey a store-house of information on the various subjects on which geology bears. He was the first to make out the geologic structure of the eruptive districts of Eastern Canada.

Nor was his Canadian work limited to the Geological Survey. He was Assistant to the Canadian Commissioners for three great Exhibitions, namely, the Philadelphia Centennial Exhibition of 1876, the Paris Universal Exhibition of 1878, and the Colonial and Indian Exhibition of 1886, in London. These posts involved the making of descriptive catalogues of Canadian minerals, rocks, &c.

Selwyn was one of the original members of the Royal Society of Canada, and he held the office of its President in 1895, 6. He took an active part in the meeting of the British Association at Montreal in 1884, and the geologists who attended that meeting will remember his kindness during the excursions round Ottawa, and (after the meeting) along the Canadian Pacific Railway, during the latter of which he had a narrow escape from a mass of rock which fell across a wooden tressle-bridge as some of the party were crossing it: indeed, had it not been for his quickness in seeing the danger, there might have been damage to life or limb.

Curiously enough, the writer of this notice (with an Engineer who was also smitten by the desire of walking as far down the Pacific slope as time would allow), had passed the spot some time before. Both had been struck with signs of instability, and both had come to the conclusion (as geologist and as engineer), that something ought to happen there some day. On their return they found that it had happened, a short length of railway along which they had gone having been destroyed, luckily without damage to anyone.

Selwyn died at Vancouver, October 19, 1902.

By nature and by upbringing, Selwyn was a stratigraphical geologist, and he had a strong liking for districts of complex structure. The picking of geologic threads out of a tangled skein was the kind of work that pleased him.

He was a scholarly man, who gave much time to the preparation of reports and papers, and who expected those under him to follow his example of neatness. Moreover, he was a disciplinarian, a quality sometimes wanting in scientific chiefs. Tall in stature, quick in action, of nervous temperament, he was a good specimen of the English geologist of the early days of the Geological Survey, worthy to rank with De la Beche, Ramsay, Forbes and Jukes, and no higher praise than this would he have wished for.

Selwyn was elected F.G.S. in 1871, and F.R.S. in 1874. He received the Murchison Medal from the Geological Society in 1876, and in accepting it, on his behalf, his old friend Ramsay well said

that there was "an appropriateness in the award . . . to one who has done such excellent work among Silurian rocks in three regions of the world." He also received the Clarke Gold Medal from the Royal Society of New South Wales in 1884. In 1886 he was made C.M.G.

In addition to these honours, his name is perpetuated in Canada topographically, in connection with River, Lake, and Inlet.

There are many references to Selwyn in the "Letters . . of J. Beete Jukes," by his sister (Mrs. Browne), published in 1871, and in the "Memoir of Sir Andrew Crombie Ramsay," by Sir A. Geikie, published in 1895. These two works indeed give a history of the early days of the Geological Survey.

For details of Selwyn's work, the reader is also referred to the following papers, the first of which was published during his life:—

1899. Eminent Living Geologists: Alfred Richard Cecil Selwyn. By Dr. H. Woodward. *Geol. Mag.*, dec. iv, vol. vi, pp. 49–55.

1903. Alfred Charles Selwyn. By H. M. Ami and Dr. H. Woodward, in the Anniversary Address of the President. *Quart. Journ. Geol. Soc.*, vol. lix, pp. lxi–lxiii. Practically included in the fuller notice by M. Ami.

1903. Sketch of the Life and Work of the late Dr. A. R. C. Selwyn. By H. M. Ami. *American Geologist*, vol. xxxi, pp. 1–21. With a Bibliography (not perfect).

W. W.

ABRAHAM FOLLETT OSLER. 1808—1903.

Abraham Follett Osler was born in the neighbourhood of Birmingham on March the 22nd, 1808. He was educated at Hazelwood School, Birmingham, which was founded by Thomas Wright Hill, and carried on by him with the aid of his five sons, all of whom afterwards became men of considerable note. The school was conducted on principles that were novel, and which caused it to attain some celebrity in its day. The initiation of these principles was chiefly due to Sir Rowland Hill, whose name became so well known in connection with the establishment of penny postage.

The principles were briefly these:—Self-government and mutual responsibility, making the school, in fact, an enlightened republic; and fixed standards of merit, instead of competition, as a test of success.

The school, so far as it encouraged Mr. Osler's fondness for mechanical studies, was advantageous to him, and he became noted for his remarkable ingenuity and great industry. He carried on the printing of the school journal, made an admirable working model of a steam engine, and devoted his leisure more to the study of practical science than to the ordinary amusements of boys.

On leaving Mr. Hill's school in 1824, when he was 16 years of age, Mr. Osler became at once an assistant to his father, who was carrying on a glass business in Birmingham. Here he worked for about seven years, but in 1831 the business fell entirely into his hands. He at once remodelled it, and his artistic sense, mechanical ability, and originality of mind enabled him to develop it to a remarkable extent.

Mr. Osler's attention appears to have been first drawn to Meteorology by the Council of the Philosophical Institution of Birmingham purchasing what was, at that time, 1835, a complete set of meteorological instruments; these enabled the observer to do little more than register, at certain times, temperature, barometric pressure, amount of moisture, and the direction of the wind. Mr. Osler at once perceived that really to advance the subject of Meteorology, observations of a different character were required, and that the great thing needed was to obtain continuous records of atmospheric changes, and he immediately applied himself to contriving and constructing a self-registering anemometer and rain gauge. In this he was very successful.

The self-recording anemometer which he constructed received the varying wind-pressure on a plate of known area, supported on springs and kept at right angles to the direction of the wind by means of a vane. The degree to which this plate was pressed back upon the springs by each gust of wind was registered in pounds avoirdupois per square foot by a pencil on a sheet of paper graduated in hours, and moved forward at a uniform rate by means of a clock. On the same sheet the direction of the wind was recorded. This was done by means of a vane, and its movements were conveyed by an ingenious contrivance to a pencil which moved transversely upon a scale of horizontal lines representing the points of the compass. The curve thus drawn gave a continuous record of the direction of the wind. In addition to these, the rainfall was also recorded on the same paper. To obtain this result the rain was collected in a funnel, the top of which had a known area, and flowed into a vessel supported on a bent lever with a counterbalancing weight, and, as the water accumulated, it caused the vessel to descend, and this movement was registered by a pencil, which produced a line on a part of the paper that was ruled with a scale of fractions of an inch. When the limit of the capacity of the counterbalanced vessel was reached it discharged its contents automatically, and the pencil returned to the zero line.

The first self-registering anemometer and rain-gauge, made by Mr. Osler in 1835, was erected at the Philosophical Institution, Cannon Street, Birmingham, and a description of its work, illustrated with records obtained from it, was published in the annual report of the Institution for 1836.

Although Mr. Osler has of late years been chiefly known through the connection of his name with the self-registering anemometer, he took a large and active part in the introduction of a new era in the Science of Meteorology, and read numerous papers before the British Association on this subject.

From the time when he first introduced the principle of obtaining continuous graphic records of the direction and pressure of the wind, and of the rainfall, these methods of recording atmospheric changes became universally adopted, and every possible help and information was given by Mr. Osler to anyone desiring to construct instruments on his model.

In the course of the next few years anemometers of this type were installed—at the Greenwich Observatory, where it has been in use since 1841; at the Royal Exchange, London; at Plymouth, under the charge of Sir William Snow Harris; at Inverness, under the charge of Sir David Brewster; at Liverpool, under the charge of Mr. Hartnup; and at many other stations at home and abroad.

During succeeding years Mr. Osler expended much labour and time in tabulating and working out results from observations taken at various stations where his instruments were fixed. He showed great ingenuity and resource in his methods of graphically depicting results in such ways as would enable the eye easily to detect the characteristic features, and to compare the observations of the various stations.

His first paper was read before the British Association in 1837, when he briefly described the working of the combined anemometer and rain-gauge. At the same meeting Prof. Whewell's anemometer, recording the total mileage and direction of the wind, was described by Mr. Southwood. Prof. Whewell's instrument was the forerunner of Dr. Robinson's famous revolving-cup anemometer for measuring the wind mileage, which was shown on dials as in a gas meter.

This method of measuring the horizontal motion of the air by means of revolving hemispherical cups, on the principle worked out by Dr. Robinson, soon came into general use, and Mr. Osler adopted it as an addition to his pressure anemometer, by making the cup shaft, geared down to a low speed, propel a ribbon of paper, which was punctuated at equal intervals of time by a hammer driven by the clock, thus obtaining mean hourly velocities as well as total mileage of the wind.

At a later period, when he had made improvements in the details and construction of his anemometer, he simplified the mileage record by using a double cam that caused a pencil to rise and fall at speeds proportionate to the velocity of the wind, upon the paper moved by the clock, thus getting the curves of pressure, direction, velocity, and rainfall, in connection with time, recorded on the same sheet of paper.

Papers were read by Mr. Osler before the British Association, in 1839, at Birmingham; and in the year 1840 he gave one at Glasgow, in which he developed a method of exhibiting the relative prevalent and intensity of winds from different directions by so-called "wind stars," afterwards adopted by Capt. Fitzroy. These wind stars depict the proportionate amount of wind from each of sixteen points of the compass during a given period; he further made suggestions of applying this graphic method to observations of temperature, atmospheric pressure, and rainfall, which were afterwards followed up by Prof. John Phillips, whose very valuable results were given later, in 1846.

Mr. Osler also developed another series of monthly, quarterly, annual, and mean diurnal wind curves, which clearly illustrated the average distribution of winds during each part of the day, and for the different seasons. In these curves he noticed that the periods of calm came generally after midnight, and the periods of greatest disturbance after mid-day.

This observation led him to place mean diurnal wind velocity curves parallel to the mean diurnal temperature curve, and he found that, on reducing the two maxima and minima to the same values, they became almost identical.

Sir David Brewster, in a paper read at the same meeting, 1840, on "Barometric oscillations at Inverness," came to the same conclusion, and, referring to the outcome of his barometric and thermometric observations, made use of the following words:—"This very important and new result is confirmed in a remarkable manner by the observations of Mr. Osler at Birmingham, made at the request and expense of the British Association, which I have seen since I arrived at Glasgow—observations of inestimable value, which exhibit more important results respecting the phenomena and laws of the wind than any which have been obtained since meteorology became one of the physical sciences."

Mr. Osler often strongly urged the necessity of establishing meteorological observatories at suitably selected stations in different latitudes, so that aerial movements could be examined in tropical regions, where the action of the sun, as the great disturbing cause, is more marked, and its results more simple and regular, and also at a series of stations extending through the temperate zones, where the conditions become more complex. He maintained that if all these observations

were tabulated and worked out on the same system, much might be done to put the study of meteorology on a more scientific basis, and a better knowledge could be obtained of the laws that govern the phenomena of weather changes than can be deduced from isolated observations or columns of statistical figures.

He showed how all atmospheric disturbances were in some way related to the great trade winds, and how the character of the winds themselves, the smooth and steady northerly winds and the rough and gusty south winds, indicated their origin, the one being drawn along to replace uprisen air, and the other being pushed along by pressure from behind. He showed how the return upper currents from the tropical regions, having cooled as they flowed towards the poles, tended to descend to the earth's surface, and, meeting the lower northern current, produced the variable winds of the temperate regions. He also showed the effect of the earth's rotation in inducing eastern and western velocities to the northerly and southerly winds.

His paper at Birmingham before the British Association, in 1865, still further developed his graphic methods, and showed the interesting and valuable results that could be obtained by minute and careful comparison of observations taken at three different stations—Wrottesley, Liverpool, and Birmingham. His last paper communicated to the British Association, "On the normal forms of clouds," is published in the report of the Birmingham meeting for the year 1886.

Other subjects than Meteorology exercised Mr. Osler's active mind. In January, 1842, he gave a series of three lectures on Chronometry at the Birmingham Philosophical Institution, in which he described the various ways of measuring time from the earliest periods to the present day, fully illustrating the subject by drawings and working models specially constructed for the purpose. With these he showed the methods of measuring time by sundials, water clocks, and other forms of clepsydræ, and explained the various forms of escapement, and other essential parts of modern clocks and watches.

Immediately following these lectures he proposed establishing a standard clock for Birmingham, and he collected funds with which he procured one of the highest class, made by Dent, which was placed in the front of the Philosophical Institution. He also purchased a transit instrument and an astronomical clock to equip an observatory on the roof of the building, and himself took the astronomical observations for regulating the standard clock. By-and-bye, when he had fully established the clock's accuracy, in the public estimation, he, on one Sunday morning, altered the clock from Birmingham to Greenwich time, without mentioning it to any one, and, though the difference was remarked upon, the Church and private clocks and watches

throughout the town were gradually adjusted to Greenwich mean time, while the country generally was keeping only local time.

In 1855 Mr. Osler was proposed and elected a Fellow of the Royal Society.

Many different subjects appealed forcibly to him and benefited by his ingenuity. He was at one time interested in Craniometry, and devised and constructed an instrument for this purpose which was remarkable for its completeness and accuracy. It gave full-sized diagrams of the exact form of the skull.

In 1876 Mr. Osler finally retired from business, but his mental activity continued, and he then devoted himself to the consideration of purely scientific matters, and although, owing to his nervous constitution, he published but little, he has left behind many papers of interest, which show the great scope and originality of his mind.

In 1832 he married Mary, daughter of Thomas Clark, a merchant and manufacturer in Birmingham, and had a large family, of whom only three have outlived him. Devoted as he always was to his family, his home life was a constant pleasure to him, but his sensitive and nervous disposition did not allow of his taking part in the public life even of his native town. He was, nevertheless, a generous benefactor to Birmingham.

Canon Kingsley, when President of the Birmingham and Midland Institute in 1872, urged strongly on the Council of the Institute the great importance of founding classes for the teaching of systematic hygiene, and, in response to this appeal, Mr. Osler anonymously presented to the Institute the sum of £2,500 to enable this to be done. These classes have been from the first a great success, and are continued to the present day.

In 1883, on the completion of the new Municipal buildings in Birmingham, of which a lofty clock tower formed an important feature, Mr. Osler, prompted by his life-long interest in chronometry, presented to the town a clock and bells suitable for the tower—these are the same in size and pattern as those at the Law Courts in London.

In 1886 the work of the Council of the Birmingham Midland Institute being crippled by the want of funds, Mr. Osler met their difficulties by a present of £5,000, insisting, at the same time, that the name of the donor should not be made public. In the following year he gave a like sum of £5,000 to the endowment fund of Mason College, again under the same condition that the name of the giver be not made known, and, although the Council of the College "earnestly desired" that Mr. Osler would withdraw this restriction, he never did so.

On the establishment of the Birmingham University, Mr. Osler insisted that his subscription of £5,000 to the endowment fund should be printed on the list as given anonymously. Other institutions and individuals have to thank him for generous acts towards them.

He was a man of great mental power, very clear-sighted in all that interested him, and he fearlessly held opinions which he believed to be true. At the same time, his sensitive temperament prevented his taking the prominent position in scientific and public life which he would otherwise certainly have occupied.

Mr. Osler died at the age of 95 on April the 26th, 1903.

W. J. R.

SIR ERASMUS OMMANNEY. 1814—1904.

Erasmus Ommanney was born on May 22, 1814, the seventh son of the late Sir Francis Molyneux Ommanney. He entered the Navy in August 1826, on board H.M.S. "Albion," in which he took part in the naval action of Navarino October 20, 1827.

In 1835 he paid his first visit to the Arctic regions in H.M.S. "Cove," sent under the command of Captain J. Clark Ross in December to Baffins Bay, to rescue some whalers beset in the ice. Lieut. Ommanney received special commendation from the Admiralty for his behaviour in this dangerous service. In 1840 he became a Commander having served in the interval in the Mediterranean, and was placed in command of the "Vesuvius," one of the early type of steam vessels in the navy, in which he served for three years in the Mediterranean.

Promoted to Captain on November 9, 1846, he was at first employed in Ireland on relief measures, and then was appointed to H.M.S. "Assistance," one of the vessels sent under the chief command of Captain Horatio Austin in 1850, to search for Sir John Franklin.

In command of this vessel he did much good work. He found the first trace of Franklin's Expedition, and travelled great distances by sledge in fruitless further researches, in the course of which he mapped much coast line and obtained during two years many valuable magnetic observations, some of them in the immediate vicinity of the Magnetic Pole.

During the Russian War, Ommanney in H.M.S. "Eurydice" commanded a small squadron sent to the White Sea in 1854, when good service was performed, and some more magnetic observations obtained.

In 1855 he commanded H.M.S. "Hawke" in the Baltic and saw more service.

In 1857 he was in command of the 80-gun ship "Brunswick" in West Indies, and in subsequent years in the Channel and Mediterranean, and was from 1862 to 1864, Senior Naval Officer at Gibraltar. He did not again serve afloat, but became a Rear-Admiral in 1864, Vice-Admiral in 1871 and an Admiral on retired list in 1877. In 1867 he received the C.B. for his Arctic and other services, and in 1868 was elected a Fellow of the Royal Society as a distinguished Arctic Explorer. He was knighted in 1877, and created a K.C.B. in 1902. He received the honorary degree of LL.D. from the University of Montreal in 1885.

Sir E. Ommanney was a Fellow of the Astronomical and Geographical Societies, and was also a constant attendant at the Meetings of the British Association, presiding over Section E in 1877. He was for many years an earnest advocate of the renewal of Antarctic Exploration, and at the 1886 Meeting, brought all his influence to bear with the view of inviting public interest in the question. He went as a member of two Eclipse Expeditions, to Spain in 1870 and to Luxor in 1874. He served for many years on the Council of the United Service Institution.

He was twice married, in 1844 to Emily M., daughter of S. Smith, Esq., and in 1862 to Mary, daughter of T. A. Stone, Esq., of Curzon Street, Mayfair, and he leaves descendants.

Admiral Ommanney was an officer of conspicuous energy and lived to a great age, dying in his 91st year at his son's residence, St. Michael's Vicarage, Portsmouth, on December 21, 1904.

W. J. L. W.

Sir JOHN SIMON. 1816—1904.

John Simon was born on October 10, 1816, and died on July 23, 1904. His grandfather, a native of Montargis, in France, appears to have settled in London, for purposes of trade, towards the close of the 18th century, and married an English wife. His only son, who was educated in England, became in due time a member of the Stock Exchange, and for over 30 years (1848–79) served on the General Purposes Committee of that body, and took a leading part in its business. By his second marriage, to Mademoiselle Matilda Nonnet, he became the father of a large family, of whom the subject of this notice was the eldest. John Simon was therefore in greater measure French than English, for he was of French descent, not only through his mother, but also through his paternal grandfather.*

Simon received his education at the well-known school of Dr. Burney, nephew of the author of "Evelina." After seven years at school he spent about a year in Germany in order to learn the language. On his return to London, in 1833, he began his professional studies in the way that was, at that time, thought best fitted for the purpose. Seventy years ago, and for long after, the first step towards acquiring the requisite knowledge and skill for the exercise of the medical art was to serve an apprenticeship. In Simon's case the method had great advantages. He was apprenticed to Mr. J. H. Green, F.R.S., Surgeon to St. Thomas' Hospital, who was not only a most distinguished surgeon, but a scholar and a man of letters. Under Mr. Green's direction he spent the four years 1833–7 in the study of anatomy, physiology and surgery, and on his recommendation was appointed, in the latter year, immediately after passing his professional examination, Demonstrator of Anatomy and Assistant Surgeon in King's College Hospital. These positions he held for nine years (1838–47)—years which afforded him leisure for a variety of non-professional studies, rather literary than scientific. It appears indeed that it was not until the end of his official service at King's College that he began to take a vivid interest in physiological science, evidencing his capacity for scientific inquiry by offering to the Royal Society a paper on the comparative anatomy of the Thyroid Gland, the importance of which the Royal Society recognised by promptly electing its author to the Fellowship. In 1847 Simon was appointed Lecturer

* Notwithstanding that the name Simon was originally French, it was usually pronounced as if it were German.

on Pathology at St. Thomas' Hospital, and published an introductory discourse, "On the aims and philosophic method of pathological research," which is remarkable as showing the grasp he had at this early period of the fundamental principles of a branch of science which had then barely come into existence. This was followed in 1859 by the publication of the course of lectures on "General Pathology," which will be referred to further on.

In 1848 Simon married Jane, daughter of Matthew Delaval O'Meara, who had served with distinction as Commissary-General in the Peninsular War. Two months later he received the important appointment of Officer of Health to the City of London, which he held for seven years. His work in this capacity is embodied in his City of London Annual Reports. These were separately published in 1854, and in part republished by the Sanitary Institute 33 years later.

In 1855 Simon entered the service of the State as "Medical Officer" of the Central Sanitary Authority. The post was, in the first instance, attached to the General Board of Health, which came to an end in 1858. The Legislation of that year devolved the functions of that Board relating to Public Health on the Lords of the Council. In 1859 an Act was passed by which the appointment of Medical Officer was rendered permanent, and the duty imposed on the holder of it of advising and acting for his Ministerial chief (the Vice-President of the Council for Education) on all matters relating to sanitary administration. This office was then held by Mr. Lowe (afterwards Lord Sherbrooke), to whose active intervention the successful carrying out of the arrangements above referred to was in great measure due.

From the moment that Mr. Simon's position was secured, he lost no opportunity of using the resources of his office for the advancement of Pathology. Even before this was accomplished he had written an important Report on the preventability of certain kinds of premature death, which was founded on the elaborate statistical investigations just before contributed to the Board of Health by the late Dr. Headlam Greenhow, F.R.S. These were subsequently published under the title of "Papers relating to the Sanitary State of the People of England,"* a work which has since become one of the classics of sanitary science. Simon was thus able at once to take the position that "where preventable disease prevailed in excess, the ætiological facts ought to be ascertained by *medical* investigation for the information of the general public, the Government, and the Legislature."

The Board of Health had not been in possession of the necessary machinery for making such inquiries, but as soon as the new authority

* "Public Health Reports," edited by Edward Seaton, M.D. Lond., 1887, pp. 427–488.

was established, Simon presented a "reasoned programme"* of the sanitary improvements which he considered to be most necessary—a programme which was faithfully carried out during the succeeding years of fruitful administrative work. Among the inquiries which were then initiated, one may be mentioned which was of special importance, namely, that which was entrusted by Mr. Simon to Dr. Buchanan, F.R.S., his distinguished successor.† Its purpose was to ascertain the condition of towns in which, during the preceding decade, works of sanitary improvement had been carried out in a thorough and efficient manner, as compared with that of others in which no such improvements had been made. The results of this investigation afforded stronger evidence than had ever before been obtained of the saving of life by good sanitation, and were of great value in quickening popular interest in the subject, as well as affording a secure basis for future legislation. After twelve years of successful progress, the function of the Privy Council as Central Authority was, in its turn, brought to an end by the legislation of 1871. By the Local Government Act of that year, the previously existing Poor Law Board was replaced by the newly constituted Local Government Board, of which the organisation and functions did not differ materially from those of its predecessor, the Poor Law Board. To this Board the future sanitary administration of England was committed. The lines on which it was organized were inconsistent with the principles by which, on taking office, Mr. Simon had, in harmonious co-operation with successive ministerial chiefs, been guided in the discharge of his official duties. These principles were first, that the sanitary administration of the country should be under the *direct supervision* of the medical department; secondly, that the relations of the department with local sanitary authorities should be such as to enable it to bring its influence promptly to bear on them in case of default of duty; and thirdly, that the saving of human life by the prevention of disease should be regarded as the highest motive of official action. As in all these respects the system of sanitary government initiated in 1871 seemed to be inconsistent with the efficient working of the medical department, Simon, after a few years of contest, during which he endured with, perhaps, too little patience the constantly recurring pinpricks of official interference, asked and obtained leave to retire.

The investigations which Simon set on foot during the first half dozen years after his appointment, although, in the strictest sense, scientific, were intimately connected with the administrative work of

* "English Sanitary Institutions," London, 1897, p. 269.

† "Public Health Reports," *loc. cit.*, pp. 262–272.

his office. But from 1866 or 1867 onwards he, with the cordial approval of his ministerial chief, set on foot inquiries of a more theoretical nature. These were undertaken *without reference to immediate practical results*, in the confidence that, as Mr. Simon put it, "they would lead to more precise and intimate knowledge of the causes and processes of important diseases, and would thus augment more and more the vital resources of preventive medicine." The expenses of these investigations were, in the first instance, provided for by special Parliamentary grants, but in 1870, when Mr. Lowe was Chancellor of the Exchequer, an annual subsidy of £2,000 was voted by Parliament for the "Auxiliary Investigations for the advancement of Medicine," to be conducted by the Medical Department. Thus preventive medicine profited a second time by the enlightened appreciation of this distinguished statesman.

Happily the legislation of 1871 did not affect this grant, so that until his resignation Simon had ample means for carrying on the researches which he thought important. These related chiefly to fundamental ætiological questions concerning the nature of infection, the pathological anatomy of tuberculous disease, the relation between the tuberculous and the traumatic infections, the ætiology of cancer, and other equally important subjects. In all these inquiries Simon obtained the co-operation of men who had the necessary time and technical training for the work committed to them; and it may be noted that in his official reports of the results, he invariably gave the principal credit for whatever new discoveries were achieved, to his coadjutors, even when these additions to knowledge resulted from investigations initiated by himself.

Having arrived at this turning point in the history of Mr. Simon's official life, it will not appear out of place to summarize the outcome of his twelve years of active effort (1859–71). No impartial person will question that they were also years of achievement. As a sanitary administrator he had begun by realizing that the most serious obstacle to effectual work was want of sufficient information as to the nature of the dangers it was his business to guard against. By means of his Annual Reports, particularly those published during the earlier years of his tenure of office, he had shown the nature of the information wanted, the means by which it must be acquired, and how it could best be rendered available for the public service.

He held it to be necessary that special investigations should be promptly made in all parts of England, wherever and whenever the local prevalence of disease afforded ground for apprehending the existence of epidemics, or the prevalence of local, occupational, or other insanitary conditions. He also considered it to be indispensable that

special laboratory researches should be undertaken by the department, for the elucidation of obscure ætiological questions and for bringing the data so obtained to bear on sanitary administration. In both of these directions the sanitary administration of the country had, in 1871, attained a high degree of efficiency. The thorough supervision of local sanitary authorities had been rendered possible by the appointment of a staff of highly qualified medical inspectors, and, in consequence, the action of the central authority had become more and more influential, so that, although its functions were for the most part only advisory, its advice was promptly and punctually complied with.

Whether the circumstances which induced Mr. Simon to withdraw from the public service were sufficient to justify that act, may well be questioned; but it can scarcely be doubted that much advantage would have accrued to this country if free scope had been given to the principles and methods which he inculcated.

In the preceding paragraphs I have referred exclusively to the years which led up to Simon's withdrawal from active life. As regards the next twenty-eight years, it will be sufficient to indicate his principal occupations, and notice one or two events of his life. The same year in which he resigned his official position, he was appointed "Crown Member" of the General Medical Council; and a few years later (1881) served on the Royal Commission on the Constitution of the Medical Profession. In 1878 he was elected President of the Royal College of Surgeons, and about the same time presided over the Pathological Society. In 1881, in co-operation with his friend Mr. Kingdon, afterwards Master of the Grocers' Company, Simon advised the Company as to the best way of employing an annual grant for the advancement of sanitary science. The plan recommended was the establishment of research scholarships, with reference to which he advised that the conditions of candidature should be unrestricted by any conditions excepting age, and that each candidate should be required to set forth the scope of the investigation proposed by him, and to submit evidence of his qualifications for the work. It was further recommended that on this evidence a selection should be made by a committee of the Company, with the advice of scientific "Assessors." This scheme was carried out by the Company on the lines of the above proposals. At first some difficulty was experienced in finding candidates of adequate scientific attainments, but as time went on, and the opportunities for training in the scientific methods required became more accessible, this difficulty vanished. For many years the Grocers' scholarships have enabled some of the best of our young pathologists to devote themselves to researches of practical value in preventive medicine.

I now propose to supplement the short sketch contained in the preceding paragraphs by such more detailed information as will be of service to the reader in forming an estimate of Mr. Simon's attainments as a biologist, as a pathologist, and as the adviser of Government in matters relating to public health.

Of Simon's two researches in comparative anatomy, one, on the "Comparative Anatomy of the Thyroid Gland,"* was contributed to the Royal Society in 1844. To the other, on the structure, development, morphology, comparative anatomy, and physiology of the thymus gland, the Astley-Cooper† prize was awarded the same year. The exactitude of his observations, many of which were at that time new, his reluctance to take anything for granted that he had not confirmed by his own observation, the care he bestowed on the many hundred original dissections and microscopical preparations he made, all serve to show that comparative anatomy was the loser for his not choosing it as the branch of science he was to follow. Until he took up the study of the two organs, there had been a great deal of confusion in the discussion of their morphology in the lower vertebrates. In some orders of mammals, in birds, and in some reptiles and amphibians, Simon was the first to describe, or to distinguish, the *Thymus.* He further established an inverse proportion between its persistence in an animal or group of animals, and the muscular activity of that animal, and concluded therefrom, and also from his failure to recognise it in the gill-breathing vertebrates, that the chief function of the thymus consists in its supplying fuel for respiration during its period of activity.

The *Thyroid* he described for the first time in fish and in certain reptiles, and showed that while its position varies in the different genera of fish in which it is present, its relation to the vascular supply of the brain is the same, and resembles that which prevails in the higher vertebrates.

As we have seen, Simon first obtained the approval of the Royal Society as a biologist. But it was as the first English systematic writer on *Pathology, i.e.*, on the science which deals with the causes and nature of disease, that he first became known to students of medicine. The lectures at St. Thomas' Hospital‡ appeared in 1850. The foundation of the new science had been laid by Henle, and Virchow was attracting to Würzburg such English students as desired to learn the new methods of pathological research. The fact that Simon was the English exponent of the rapid progress of discovery in Germany gave the lectures a special interest; for, at that time, the notion that the functions of the living organism could be best understood by bringing them into relation to the processes of non-living nature, and best

* "Phil. Trans.," vol. 134. † "Physiological Essay on the Thymus Gland."
‡ "General Pathology," published by Henry Renshaw, 1850.

investigated by the experimental method, was new to those who approached questions relating to the causation of disease from the point of view of practical medicine. Simon's aim was to show that the same methods which, during the preceding decade, had yielded such remarkable fruits in physiology, could also be applied to the study of disease; and that neither of these branches of knowledge presented any exception to "the unbroken uniformity which prevails in the operation of natural laws."

The comparison of these lectures with Simon's later writings shows us how, proceeding from the principle set forth in the words I have quoted, he followed, during the 25 years of his active life, the rapid progress of anatomical, clinical, and experimental discovery; taking care not to be in front of ascertained fact, however far he might be in advance of current teaching. From first to last, the side of pathology which chiefly interested him was the ætiological, not merely because the knowledge of the origin of a disease is indispensable for the understanding of its nature, but more directly in consideration of the immediate practical value of such knowledge, as suggesting the means of prevention. Among ætiological questions, those of the specific causes of infective diseases, and the manner in which they produce their characteristic effects, were very fully considered in relation to the doctrine of *contagium*.

This now unfamiliar word was employed by Simon to designate the material agent by which infection is communicated from the diseased to the healthy body. In the lectures he attributed to "true contagia" two characteristic endowments, namely, that they are able to produce their characteristic results when given in the smallest conceivable doses, and that "they undergo, in the body on which they act, a striking and singular increase; which increase, if recovered from, confers on its subject immunity."* As to the way by which this happens, he speculates as follows: a certain organic material A (the *contagium*) enters into particular relations with B (a normal ingredient of the blood). The effects of their coming together are (1) the utter destruction of B, and (2) that A undergoes an immense augmentation. "What has become of B? Whence has the new A been derived? It is difficult to avoid the conviction which arises with almost logical certainty, that the increase of one material and the decrease of the other have stood in an essential mutual relation; that, in short, it has been a process of *conversion;* that the essential relation of the two matters (that derived from *without*, and that contained *within* the blood) has consisted in the ready convertibility of the one into the other; that the specific power of the virus is its power of effecting this transformation, and no other."†

* Lecture XII., p. 258.

† Lecture XII., p. 264.

Accordingly susceptibility depends on the presence of B, immunity on its complete conversion. If this is admitted, it follows that the human organism must be inhabited by as great an assortment of specific susceptibilities as there are communicable diseases; for, on the one hand, the specificity of the contagium A necessarily carries with it that of the substratum B, by the transmutation of which it is produced, and, on the other, the immunity from a specific contagium which the hypothesis accounts for as resulting from the transmutation, is a thing quite as specific as the previous susceptibility. It follows from this that the material of contagium must be a constituent of the blood not essential to the performance of its nutritive functions (for otherwise the acquirement of immunity would be fatal to life), the characteristic facts relating to it being first, that it is convertible into contagium as the immediate result of infection; secondly, that as the consequence of that transformation, it becomes liable to catalytic expulsion from the organism; and thirdly, that its elimination is equivalent to immunity.

Whether or not Simon's reasoning can now be regarded as adequate, it is of great interest to note that the fundamental notion of the normal susceptibility of the organism was clearly enunciated by him 54 years ago, as serving to explain the facts of infection as they then presented themselves, and that now, after half a century of progress, the same notion finds expression in terms more elaborate, but not essentially different from those which were then employed.

It was not until the seventies that Simon again wrote on the subject. The great discoveries which, in the following decade, afforded ground for the inference that each specific infection centres round a specific concomitant micro-organism, had not yet been made, and Simon was not destined to take part in them. To him the settlement of the identity of each true contagium by the uniformity of its operation as tested experimentally, was of greater interest than its biological classification. He was well aware that in one or two instances it had been proved experimentally that "the specific microphytes of disease" can be "conducted through a series of artificial cultivations," and that "germs thus remotely descended from a first contagium will, if living animals be inoculated with them, breed in these animals the specific disease"*; and he anticipated that specific organic forms might prove to be the "essential originators of infective processes"; but he conjectured that the progress of discovery would be slow. In this he was mistaken. At the moment that he thus wrote, Koch had already in hand the investigations which led to the discovery of the bacteriological method, and in a few more years conjecture was transformed into fact.

* "Public Health Reports," ed. by Edward Seaton, M.D., London, 1887, p. 578.

In connection with the subject of contagion, reference should here be made to the doctrine strongly enforced by the early sanitary reformers who were Simon's immediate predecessors, that *filth* was the enemy against which all measures for the prevention of zymotic diseases must be chiefly directed. Recognizing that the belief in the dependence of disease on dirt has a foundation in fact, he did his best to bring its essential characters as a cause of disease into prominence, so that its special meaning as a term to be commonly employed in sanitary science should be well understood and determined. In the introduction to a paper, published in 1874, on the subject, he shows that sanitary improvement has always had for its foundation the broad knowledge that filth makes disease. He then gives in detail the reasons for concluding that filth, considered as a source of danger to health, is never definable in chemical terms, and finally limits the technical application of the word to those kinds of uncleanness which contain, as their essential ingredients, morbific "*ferments and contagia.*" He leaves the question open whether the products of putrefaction are necessarily morbific, but strongly objects to the assumption that the presence or absence of offensive smell is to be considered as evidence of infectiveness. In the battle that had to be fought in Simon's time for cleanliness in public life, it was necessary to use plain words intelligible to the ordinary reader.* In our pre-bacteriological ignorance, we had, at that time, no direct knowledge of the enemies we had to contend with, so that hand-to-hand fighting was out of the question. The best that could be done was done. The best existing information was brought to bear for the enforcement of cleanliness and of the rapid removal of dangerous refuse, with results to the public health which could scarcely have been surpassed had we been possessed of our present knowledge.

Of the scientific inquiries which were initiated by Simon in connection with his official position, none were more fruitful than those relating to the ætiology of pulmonary tuberculosis. Towards the end of the sixties, the subject presented itself to his consideration from two points of view—from that of the local and occupational conditions which had been recently ascertained to be operative in determining its prevalence, and from that of experimental evidence of its infectivity. A mass of new information as to the production of consumption by dusty atmosphere and defective ventilation had been brought together by means of local inquiries. On these followed the very remarkable investigations of Dr. Buchanan, showing that, in the absence of any personal conditions affecting the population, the drying of the soil brought about by works of sewerage in towns had led to a marked

* *Loc. cit.*, pp. 451 *et. seq.*

diminution in phthisis.* The two facts above referred to, namely, the injurious influence of dampness of soil and the liability of persons following indoor occupations, afforded ground for regarding phthisis as a *preventable* disease, and consequently for attaching the utmost importance to the acquirement of information as to its nature and ætiology.

At the very time that these important investigations were in progress, the discovery was made in France that tuberculous disease could be communicated by inoculation to animals. Simon promptly recognized "the immense pathological consequences which it involved," and initiated (in 1867) an experimental inquiry as to the facts. By elaborate and multiplied anatomical investigations it was ascertained that the disease so produced was identical in its essential characters with tubercular disease in man; and from this fact, in connection with what was previously known as regards "the mode in which tubercle in man tends to spread infectively from its original site to secondary and tertiary sites in the affected body," it was concluded that tubercle in man "must be a specific zymotic disease."† But the scope of this conclusion was limited by the observation that in certain animals a series of pathological changes, scarcely distinguishable in their development from tuberculosis, occasionally presented themselves as the results of localized traumatic infection. The result of this observation was to throw doubt on the ætiological specificity of the contagium of tubercle—a doubt which was not completely removed until Koch, a few years later, discovered the tubercle bacillus.

As a writer on preventive medicine, Simon is distinguished from most others by the higher level of the standpoint from which he regarded the responsibilities of the State and of the individual. The two spheres—philanthropy and public duty—were, in his conception of them, one. He imposed on himself and on those who worked with him the strictest punctuality in the discharge of public duty, but was not the less dominated and guided by motives higher than those of mere official obligation. Of these motives the dominant one was the desire to help the poor, to mitigate the miseries which penury brings with it, and to save life. After these came the desire to work for the same ends by adding to the sum of human knowledge. His views as to the philanthropic aim which should actuate all sanitary efforts can be best learned from the introductory chapters of the work on "English Sanitary Institutions."‡ Readers who knew Simon will understand the feeling with which, in one of these chapters, entitled "Mediæval philanthropy," he writes of the wonderful outburst of Christian

* *Loc. cit.*, pp. 335–338. † *Loc. cit.*, p. 342.
‡ "English Sanitary Institutions," London, 1897 (2nd edition).

benevolence which was awakened by St. Francis, whose life-work presented to the world such an ideal of good-doing as had never before been witnessed. The motive which he regarded as essential to the successful carrying out of all genuine philanthropic work must be the same as that which actuated St. Francis, the "servant of the poor*"; all such work, and particularly the prevention of disease, being, in Simon's judgment, only possible to those who are resolved to give "heart, as well as brain and hand, to the service of the least of mankind"; "skill is only half our equipment."

The chapter from which I have just quoted is followed by others relating to what Simon designates as the "growth of humanity in British politics." These have a special interest as bringing before us the views he entertained as to the influence on sanitary progress of religious and philanthropic movements in modern times. Just as in the 16th century the preaching of St. Francis let loose the springs of Christian charity in Italy, so the revival of religion in the 18th century in our own country, bore similar fruit in making men more willing to love their neighbours as themselves.† The reform of prisons, the repeal of cruel penal legislation, the abolition of slavery, and many other advances in the same direction, which were effected during the second half of the 18th century and the beginning of the 19th, are referred to by Simon as affording evidence how profoundly public opinion and feeling were stirred, during that period, to sympathy with the destitute, the miserable, and even with the criminal; and how these philanthropic movements prepared the way for the sanitary reforms of the first two decades (1838–1858) of the reign of Queen Victoria.

I venture to hope that no reader will deem that I have occupied too much space in bringing under his notice the views entertained by Simon as to the power of high motive to inspire conduct, whether private or public. No one will question that he was possessed of splendid qualities, both as a man of business and as a man of science. It may not be so apparent that the source of these qualities lay deeper than the mere conscientious obedience to private and public obligations. To those who desire to satisfy themselves that his life and conduct were governed by these high ideals, we recommend the reading of the "English Sanitary Institutions."

Sir John Simon was made C.B. on his retirement from office, and K.C.B. in 1887. He received the honorary degree of D.C.L. of Oxford in 1872, and the LL.D. of Cambridge in 1882. The Buchanan Medal of the Royal Society was conferred on him in 1897.

J. B. S.

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* *Loc. cit.*, p. 49.

† *Loc. cit.*, chap. viii., p. 128.

GEORGE SALMON.* 1819—1904.

GEORGE SALMON was born in Dublin on September 25, 1819. He came of a respectable Cork family, and received his school education in his own county. He matriculated at Trinity College, Dublin, when only fourteen, and graduated in the year 1838. He was elected to a scholarship in classics in 1837, and at the honour degree examination in 1838 he obtained the first Senior Moderatorship in Mathematics. In 1840 he was awarded the Madden's premium on the results of the Fellowship examination having, in the opinion of the examiners, "best deserved to succeed if another Fellowship had been vacant." In the following year he was elected to a fellowship, and to the end of his long life he remained in the closest contact with Trinity College. He died in the Provost's House on January 22, 1904.

A Fellow of Trinity College receives the nominal salary of £40 a year, Irish currency. He is, however, elected, as a matter of course, to a tutorship, generally immediately after obtaining his Fellowship, although he may have to wait some little time for a vacancy. Furthermore, the Board, which is the supreme governing body of the University, is composed of the Provost and seven Senior Fellows. The Provost is appointed by the Crown. The Senior Fellows attain their positions in virtue of seniority.

A tutor is required to lecture twice a day during term, to assist at the ordinary examinations and to advise and direct his pupils. As a rule, the tutorial lectures are delivered to classes of from fifteen to twenty-five pass-men. Frequently a tutor, especially a man of marked ability, is appointed honour-lecturer, and he may be re-appointed year after year. An honour-lecturer is relieved of one of his classes of pass-men. Such was Salmon's tutorial work until he received the Regius Professorship of Divinity in 1866.

In accordance with the old rule which required Fellows of Trinity College to take Holy Orders, Salmon was ordained in 1844. He began at once to take part in the work of the Divinity School, as an assistant to the Regius Professor of Divinity, a post he held for twenty years. "His duties in this department were not very exacting, but they kept alive his interest in ecclesiastical questions. He was early recognised as a preacher of ability. His sermons were marked by originality of conception, vigorous common sense in the treatment, and a bold and striking, though unadorned style."† In 1852 Archbishop Whately

* The notices in the *Times* and in "Nature" have been of great assistance in drawing up this account of Dr. Salmon's life and work.

† The *Times*' obituary notice.

made him one of his examining chaplains. In 1858 he was appointed Donegal Lecturer in Mathematics, and he taught engineering students the elements of the calculus. In 1859 he proceeded to the degrees of B.D. and D.D., and he published in 1861 his first series of sermons preached in the Chapel of Trinity College.

It is evident, from what has been said, that Salmon's duties as tutor and lecturer were not of the highest order. There was much routine work in his lecturing, and much vexatious waste of time in supervising a large chamber of pupils. There was little scope in his subordinate position for the exercise of his strong personality in effecting direct improvement in the Mathematical or in the Divinity School. And owing to the method of appointing honour-lecturers, he had but little chance of permanently influencing the abler mathematical undergraduates with whom he came in contact. During these years, however, he produced indirectly in the teaching of mathematics an enormous change which extended far beyond his own university. He published his four great text-books—the "Conic Sections" in 1847, the "Higher Plane Curves" in 1852, the "Lessons Introductory to the Study of the Modern Higher Algebra" in 1859, and the "Geometry of Three Dimensions" in 1862. To a great extent those books remain the standard works on their respective subjects. They have been widely translated, and they have passed through numerous editions in the translations as well as in the original. Moreover, during his tutorship, Salmon published most of his original papers.

It was natural that a man of Salmon's originality and versatility should have desired a post of greater responsibility and of wider scope for initiation, as well as freedom from the irksome duties of a tutorship. In 1862 Salmon was regarded as the fitting successor to Graves in the chair of mathematics. Hamilton, who was working with the greatest vigour on his "Elements of Quaternions," was ineligible even had he desired to exchange the chair of astronomy for that of mathematics. At that time an examiner for Fellowship was of necessity a Fellow, but Hamilton had never sat for Fellowship. Acting on the advice of his friends, Hamilton had notified to the Board that he was a candidate for the Professorship of Mathematics when it was vacant in 1843. "Their answer through the Registrar, Dr. Wall, was an inquiry whether he intended to present himself as a candidate at the next Fellowship examination, and an intimation that in that case it would be requisite for him '*to get into full orders.*' This reply concluded the negotiation."* Salmon laboured under no such disability. Next to Hamilton he was the most distinguished mathematician in the University. "He was an admirable teacher," says Sir Robert Ball, who

* Graves' "Life of Hamilton." Vol. ii, p. 423.

attended his lectures on conics and on elementary theoretical dynamics.*

Thus his qualifications were such that his election to the Professorship of Mathematics was a foregone conclusion had he become a candidate. However, about the same time the Archbishop King's Lectureship in Divinity fell vacant, and understanding that a junior Fellow who was his senior by two years would not apply, Salmon relinquished his claims on the Professorship, as he believed he would certainly obtain the Lectureship. The junior Fellow changed his mind after the chair of mathematics had been filled up, and the less distinguished but more senior man succeeded to the Lectureship. To Salmon's bitter and lasting disappointment he was forced to remain a tutor. At last, in 1866, after twenty-five years of tutorial drudgery, Salmon was made Regius Professor of Divinity, and consequent on his appointment he resigned his Fellowship.

It may be asked how such a state of affairs could have been tolerated: why did Salmon's university abuse his keen intellect by compelling him to deliver elementary lectures to small classes in mathematics, or, as it may have been, in logics or in classics? Why was the initiative of a strong man cramped and dwarfed by twenty-five years service in subordinate positions? The answer is that just before Salmon's election to Fellowship great changes had taken place which retarded enormously the rate of promotion in the university. The rate of promotion may be most conveniently measured by the reciprocal of the period elapsed from election to Fellowship to co-option on the Board. At present the period averages 39 years. In Salmon's case, had he been able to retain his Fellowship, it would have been slightly shorter, and after 35 years' service he would have attained a place on the governing body. At the time of Salmon's election to Fellowship, the average period was about half its present amount, and not very long before it was much shorter still. The causes of this startling growth of stagnation are due to the cessation of church preferments, to the abolition of the celibacy statute, and to a levelling-up process in the method of paying the tutors. The salary of a tutor used to depend very largely on the number of his pupils. A tutor lectured his own pupils, and no limit was imposed on their number. Doubtless this arrangement was in many ways defective, and it was discarded for the present plan, on which a tutor does not derive any very great pecuniary advantage from a large chamber of pupils, does not necessarily teach his own pupils, and cannot accept more than a definite proportion of the matriculating students. On the other hand, an unsuccessful tutor in the olden times had little inducement to remain in College unless he

* "Proc. London Mathematical Society." Ser. 2, vol. i, p. 23.

happened to be engaged in some scholarly work. In that even the would soon obtain a professorship. Otherwise he would retire on one of the numerous college livings. Further, any member of the University of note had a good chance of a bishopric. Hamilton's predecessor at the Observatory left it for a bishop's palace just ten years before Salmon entered college. The number and the value of ecclesiastical offices steadily declined, and the college patronage was abolished by the Disestablishment of the Church of Ireland in 1869. Lastly, the celibacy statute was repealed absolutely the year preceding Salmon's election to Fellowship, and, although dispensations permitting the marriage of certain Fellows used occasionally to be procured, this repeal of the statute must have tended to increase the stagnation.

In 1866 Salmon became Regius Professor of Divinity in succession to Dr. Butcher, who had been consecrated Bishop of Meath. From this time he ceased to work at mathematics save at the Theory of Numbers, and the later editions of his mathematical works were brought out under the supervision of Mr. Cathcart, Fellow and Tutor of Trinity College. It is given to few men to attain to the first rank of investigators in two distinct provinces; but, great as was Salmon's reputation as a mathematician, it was probably equalled in later years by his fame as a theologian. His masterly "Introduction to the New Testament" is probably the most powerful polemic in the English language against the Tübingen school of critics. For the "Dictionary of Christian Biography" he wrote many of the most important articles, chiefly on the Christian writers of the second century, a period of which he made himself complete master. As lately as 1897 he published a powerful essay on the criticism of the text of the New Testament. Although he was never offered a Bishopric, no man has commanded such influence in the Church of Ireland since Disestablishment as did Dr. Salmon. In politics he was a strong Conservative.

The Disestablishment of the Church of Ireland, the reconstruction of its finances, and the revision of its formularies brought new demands upon Dr. Salmon. The Bishop of Derry said in the memorial sermon preached in the Chapel of Trinity College—"In our synods he was a most formidable debater, a most persuasive advocate. If the true function of eloquence be to win an audience, he was among the greatest speakers I ever heard; nor do I for a moment believe that his artless methods were unconscious, or wanting in the highest art." And again —"In the Councils of the Disestablished Church with what confidence they followed him. When old age had reduced his voice almost to a whisper, how the whole Synod hushed itself, and settled down to catch every word he murmured. There was a homage more exquisite than applause could give; admiration was in it, and desire for that low-

voiced wisdom; but there was also the gratitude of men who owed him much."

While he had a fairly free hand in the control of the Divinity School, the loss of his Fellowship apparently had debarred him from having any more important share in the management of the University. This he resented, and he is said to have annoyed the members of the Board by declaring in the Synod that the only difference between Junior and Senior Fellows is that the latter are the longest livers. In 1874 he was chiefly instrumental in the origination of the Academic Council—"to co-operate with the Board and have a share in the regulation of the Studies, Lectures, and Examinations, and in the appointment and election of Professors." By a strange irony, when he became Provost, he did everything in his power to render this Council impotent.

In 1888, on the death of Jellett, Salmon was admitted Provost of Trinity College. He was then in his sixty-ninth year, and he held the office longer than any Provost since the Right Hon. Hely Hutchinson, who died in 1794. He was also the first Provost since Hutchinson who was not a Fellow at the time of his election. It was no light task to which he was called. The governing body of the University of Dublin consists, as has been said, of the Provost and the seven Senior Fellows, the Provost being appointed by the Crown, and the Senior Fellows attaining their position by virtue of seniority. This board transacts practically all the business of the University. Its members hold the offices of vice-provost, registrar, bursar, senior lecturer, senior dean, catechist, auditor, and senior proctor. In addition, it not unfrequently happens that a member of the board is librarian, or that he takes part in the examination for fellowship, or in some other important examination. There is nothing to correspond to the Cambridge syndicates, unless it be the medical school committee or the academic council, and of the former a member of the board is chairman, while at least three senior fellows and the provost have belonged to the latter since its inception, the provost being the *ex officio* chairman. Enough has been said to show the difficulty of Dr. Salmon's office as the head of a responsible board overloaded with duties of the most multifarious kind—a board composed of eight men whose united ages at one time approached, if they did not exceed, the magnificent total of five hundred and eighty years. "There is, said Salmon, one thing worse than an incompetent Bursar, and that is an indispensable one," when only one member of the board was fit to undertake the arduous office.

The period of Salmon's Provostship was in many respects a critical time in the history of Trinity College. The evils spoken of had

grown to a head. The Senior Fellows were not what they had been—men co-opted in the prime of life, who had escaped the allurements of matrimony and the seductions of great ecclesiastical positions. They were the survivors of a set of men whose constitutions had been most thoroughly tested by the rigours of an appalling examination. Since Dr. Salmon obtained Fellowship, the number of professorships and lectureships has been doubled. Many of the professorships then held by Fellows or by ex-Fellows are held by Fellows no longer. A new and most important body of men has come into existence—the non-Fellow professors—men hardly thought of in the days when all power and all authority was vested in the Provost and the seven Senior Fellows. One might have anticipated that he who had done so much in founding the Academic Council, and who had felt so keenly the subordination of his former positions, would have been instrumental in drawing closer together the members of the teaching staff. It may have been that his initiative was blunted by his twenty-five years of tutorial duties. It may have been that his duties as Provost—for many years the one really strong man on the Board—were so laborious that he had little time to consider matters which did not claim his immediate attention. There can, however, be no doubt that in later years his sympathies did not lie with the development of science. As a member of the Board of Intermediate Education, he did not take part with those who tried to foster the study of science in the secondary schools in Ireland.

While it may be questioned whether he did all that was possible to widen the scope of her usefulness, Trinity College must ever be grateful to her late Provost for the noble conservatism with which he defended her independence. He was willing to afford Roman Catholics every facility for religious exercises within the walls of Trinity College, but he would suffer no clerical interference, whether from the Church of Ireland or from the Church of Rome. The University which gave Sylvester the B.A. degree, which his own University refused because he would not subscribe to the Thirty-nine Articles, retains its old spirit of tolerance. The remaining tests were swept away by the Tests Act of 1873.

Salmon's power and influence were such that it was difficult, if not impossible, to carry out any change of which he disapproved. It is true he did not favour rendering Greek an optional subject, or admitting women to the University of Dublin. But these changes were made in his extreme old age, when he had grown weary of prolonged controversy. He appeared to take the keenest delight in fighting a case. However carefully prepared his opponent might be, Salmon generally found a weak part in his armour. He would not always attack an obvious defect in a proposal; he would employ the

most fantastic and ingenious reasoning to show that under certain circumstances the plan would not work, and he would not be satisfied until he got the worst of the argument; or he would use his inimitable powers of ridicule to make the thing appear absurd. Yet no one could be more direct in his conversation, in his writings, even in his funeral sermons.

Salmon's generosity was as unbounded as it was unostentatious and disinterested. His hospitality was splendid, and of the kindliest nature. He shone pre-eminent in whatever company he might be found. His after-dinner speeches were deservedly reckoned among the chief attractions of public dinners in Ireland, and those who had the good fortune to breakfast quietly with him have not been able to forget the charm of his simplicity, of his humour, and of his kindliness.

His figure was well known in Dublin—nearly every afternoon he might be seen wandering through the streets. He was a great lover of music, a great chess-player, an omnivorous reader of novels. His fund of amusing stories was inexhaustible. His jokes were circulated through the clubs. Men of all classes and creeds read his theological works and talked of them. They "were no sooner published than the learned men of two continents acclaimed them; and their men of letters smiled over controversies more witty than anything since Pascal, and of a humour more benign than his."* He had no taste for metaphysics; he despised rhetoric; he cared little for painting or architecture, and for poetry he did not care at all. Salmon's constructive faculty was not remarkable when judged by the exceptionally high standard of his other brilliant gifts. His destructive power, for example, was immense, and it is known that in his later years he satisfied himself he had demolished some of the intellectual edifices he himself had raised. He had a marvellous capacity for separating the grain from the chaff of a mathematical or of a theological argument, and what he retained he generally adorned. He excelled in the use of happy illustrations of the simplest but of the most telling nature. No less wonderful was the rapidity with which he grasped an argument and the readiness with which he replied. A stranger in the synod hall might, during the course of a debate, have looked pityingly and half contemptuously at an ungainly and rather untidy old clergyman, scribbling hastily and without interruption on little scraps of paper. He might have seen that the writer was not taking notes of the speeches, but was working arithmetic, searching for primes or finding the recurring periods in their reciprocals. He would be surprised when he saw this strange figure struggling to his feet and proceeding to talk to the synod. His surprise would give place to astonishment

* The Bishop of Derry, *loc. cit.*

and admiration when he found that Salmon had missed no point in the long debate, had assimilated everything, and was explaining his views with an incredible wealth of homely illustration, with abundant wit, and with matured common sense.

For many years Salmon was greatly attracted by the theory of numbers. He said it almost amounted to a disease with him, and he regarded his work on it as frivolous or useless. Having nearly completed a book on the subject, he burned it for some unknown reason. In addition to the intrinsic fascination of the subject, he may have found that this work relieved him of boredom, or it may have served as an anodyne; and one may hazard the suggestion that the destruction of his book was a kind of penance. In his latest years he ceased working on the theory.

Salmon's first paper was published in 1844, 'On the Properties of Surfaces of the Second Degree which correspond to the Theorems of Pascal and Brianchon on Conic Sections' ("Phil. Mag.," 24); the last of his forty-one mathematical papers was 'On Periods in the Reciprocals of Primes' ("Messenger of Mathematics," 1873, pp. 49–51). The majority of his papers have reference to numerical characteristics relating to curves and surfaces, and many of these results are summarised in the great chapter "On the Order of Restricted Systems of Equations" in his "Modern Higher Algebra." It would be most unfair to Salmon to judge of his contributions to mathematics by his papers alone. He had a great dislike to the physical trouble of writing; he modestly communicated his discoveries to friends, or reserved them for incorporation in his books, so that it is a matter of extreme difficulty to say how much is his. Apart from the discovery of new facts, the methods employed in his books must have been of tremendous service in promoting the advance of mathematics. His style was characterised by complete absence of pedantry and by profound common sense. By a few words, by some geometrical illustration, he dispensed with pages of troublesome analysis. At times the great condensation of his diction may conceal from the casual student the width and the depth of his conclusions, but on referring to an original memoir from which he quotes one is amazed to find that every essential point is reproduced, and that frequently some brilliant addition has been made and left unclaimed by him.

It must not be supposed that Salmon shared the characteristic attributed to MacCullagh of shirking analysis and trusting to his great geometrical insight. On the contrary, he seemed to revel in analysis so tedious and so intricate that it would be distasteful to most mathematicians. He says: *"By means of the differential equation I

* "Treatise on Modern Higher Algebra," Art. 260.

calculated the invariant E. Its value was given at length in the second edition, where it occupied thirteen pages, but I have not thought it worth while to reprint so long a formula." To the volume which contained this elaborate investigation, and many others involving equal skill and almost equal labour, he prefixed the words: "To A. Cayley, Esq., and J. J. Sylvester, Esq., I beg to inscribe this attempt to render some of their discoveries better known, in acknowledgment of the obligations I am under, not only to their published writings, but also to their instructive correspondence." It is, however, curious that the fascination of arithmetical work should have detained Salmon on calculations such as that of E at a time when Boole's great conception was pushing on the mathematical world to feverish haste in new discovery. Salmon's treatises contain a lucid and comprehensive survey of the subjects with which they deal, so that they are almost indispensable to the advanced mathematician. They still retain a commanding position among the best of text-books for beginners. But there is wanting in them the indescribable aroma of a great classic, and something of the suggestiveness and of the poetry. They lead by the shortest way to the solution of each individual problem, and well did Cremona describe Salmon as "*il più popolare de' matematici in tutto il mondo.*"

Of Salmon's original contributions to science, the most worthy of notice are his solutions of the problem of the degree of a surface reciprocal to a given surface; his researches in connection with surfaces subject to given conditions, analogous to those of Chasles in plane curves; his classification of curves of double curvature; his conditions for repeated roots of an equation; and his theorem of the constant anharmonic ratio of the four tangents from a point on a cubic curve.

He was awarded a Royal Medal in 1868, and the Copley in 1889. He was elected into the Society in 1863. He received the honorary degrees of D.C.L. Oxford, 1868; LL.D. Cambridge, 1874; D.D. Edinburgh, 1884; D.Math. Christiania, 1902. He was an honorary member of the Academies of Berlin, Göttingen, and Copenhagen; a Fellow of the Academy of the Lincei and of the British Academy.

C. J. J.

ISAAC ROBERTS. 1829—1904.

William Roberts, the father of Isaac, was married in 1825. Like his father before him, William was a farmer, and he lived at Groesback, near Denbigh. It was here that Isaac was born, January 27, 1829. Though Isaac, while yet in his childhood, ceased to reside in Wales, he retained throughout his life his knowledge of the Welsh language, which he spoke and wrote fluently, It may also be mentioned here that all his life Isaac was passionately attached to music, as well as to science. No doubt the second purchase he made out of his savings was a microscope, but the first was a piano. He had an excellent bass voice, and in after years became an enthusiastic practising member of the Liverpool Philharmonic Choral Society.

On November 12, 1844, Isaac Roberts was bound as an apprentice for seven years to the firm of John Johnson & Son, Builders and Lime Burners in Liverpool—a firm established sixty years previously, with a reputation for good building and prosperity. Mr. Peter Robinson (the father of Isaac Roberts' future partner) had been with that firm for 30 years, and in 1847 was admitted a partner, so that Roberts completed his apprenticeship with the new firm of Johnson & Robinson. From serving an apprenticeship with freemen, Roberts became a freeman of the City of Liverpool. He was remarkable for his industry and desire for information, and was cited as an example for imitation by the other apprentices. He was by nature a student, and did not care for many of the usual amusements of young people. His evenings were passed at the school of the Mechanics' Institute in Liverpool. For his master, Peter Robinson, Roberts had a deep admiration, and tried to imitate his many excellences.

Peter Robinson died in 1855, and Roberts was then made manager of the business of the firm. In 1856 the other partner, John Johnson, died, and Roberts was engaged to wind up the contracts and affairs of the firm. In 1859 Roberts began business in a small way as a hardworking builder in Liverpool, and was very persevering, and in 1862 Mr. J. J. Robinson, son of Peter Robinson, joined him as partner, and the firm became Roberts & Robinson. It is to this partner, the lifelong intimate friend of Roberts, that I am indebted for these particulars.

The first contract of the firm was the construction of the Birkenhead Water Works, situate on Flaybrick Hill, Cheshire, and this was followed by an important undertaking for the Liverpool Gas Company. The contractor for the erection of the Lime Street Station Hotel, at Liverpool, belonging to the London and North-Western Railway Company entrusted the carrying out of the brickwork and mason's work to

Messrs. Roberts & Robinson. After a successful career as builders for a quarter of a century, the firm gave up business in 1888, and thus left Isaac Roberts in possession both of the means to provide himself with the best scientific instruments and the leisure to devote himself to their employment.

Some years before the name of Dr. Roberts became known to the scientific world, the present writer remembers hearing the late Earl of Rosse remark on the many instances he knew of men who, after a successful business career as builders, devoted a well-earned retirement to practical astronomy. It is interesting to note that yet another builder, of whom Lord Rosse had never heard, was destined to develop and carry onwards to an unanticipated importance Lord Rosse's own brilliant discovery of spiral nebulæ.

Though when at business Isaac Roberts worked with unremitting diligence and pains, he still found time to supplement an education which, in his earlier years, had been somewhat scanty. The result was that he became a recognised master of his craft as a builder. Roberts was, indeed, so much esteemed by his associates that his aid was frequently invoked as arbitrator in disputes where technical matters in building were involved.

At the commencement of his scientific work Roberts devoted himself principally to geology. The first paper he wrote was in 1869 on the Wells and Water of Liverpool, and in the following year he became a Fellow of the Royal Geological Society. In 1878 he read a paper at the British Association on the Filtration of Water through Triassic Sandstone, and it was in this year that he commenced his career as a practical astronomer.

As to the astronomical equipment with which Dr. Roberts accomplished his work, reference may be made to the interesting account given by Mr. W. S. Franks in "The Observatory," for August, 1904. Roberts commenced practical observation in 1878 with a 7-inch refractor by Cooke, which was erected at his residence, 26, Rock Park, Rock Ferry—the same home, it may be noted, which Nathaniel Hawthorne occupied when American Consul at Liverpool. In 1882 he moved his residence to Kennessee, Maghull, near Liverpool. In 1883 Roberts tells us that he made experiments in photographing stars with ordinary portrait lenses, varying in aperture between $\frac{3}{8}$ths of an inch and 5 inches. The most efficient of these was one of 2 inches aperture by Lerebours & Secretan, and he used this as a standard for comparison with the others. The comparisons were made by attaching the cameras to the declination axis of the 7-inch refractor, and taking simultaneous photographs of well-known groups of stars under precisely similar conditions.

But the great step which he made may be given in his own words ("Monthly Notices" of the Royal Astronomical Society, January, 1886):—"The result of these experiments, and comparison with Mr. Common's great photograph of the nebula in Orion, was that I gave Sir Howard Grubb an order to make me a 20-inch silver-on-glass reflector, with 100 inches focal length, the photographs to be taken directly in the focus of the mirror, to obviate any loss of light by a second reflection, the photographic telescope to be mounted on the same declination axis as the 7-inch refractor, one being the counterpoise to the other." In a foot-note he adds that—"To Dr. Huggins is due the credit for devising this most ingenious, simple and useful mode of mounting a reflector and refractor side by side; and the skill of Sir Howard Grubb is well shown in the arrangements of the instrument to perform the objects intended."

Mr. Franks records that "over a year was spent by Dr. Roberts in minor alterations and perfecting details before the instrument could be considered good enough to perform satisfactorily the work which was expected of it. From that day to this—with the exception that a Calver mirror was substituted for the Grubb in 1888 and a 5-inch Cooke camera added in 1895—the equipment remains the same as originally planned by Dr. Roberts, a fact which speaks for itself as to the patient forethought bestowed upon this pioneer instrument, which has now become historically famous."

One circumstance, however, it would ill become the present writer not to record. Before ordering the 20-inch telescope from Grubb, Dr. Roberts had obtained an 18-inch instrument from the same maker. The results were so encouraging that he decided to enlarge the equipment on the same principle as above mentioned. The 18-inch telescope thus displaced, a most beautiful instrument, was then, with characteristic generosity, presented by Dr. Roberts to the observatory of Dunsink, co. Dublin.

As to the relative merits of reflectors and refractors for celestial photographic work, there has been much controversy, and in this controversy Roberts, as might naturally be expected from his great success, vigorously upheld the claims of the reflectors. As Mr. Franks tells us, "Roberts was one of the earliest and most consistent advocates of the merits of the reflector for celestial photography, and lived to see his predilection confirmed in quarters where there had previously been a strong prejudice for refractors. His views on the relative performance of camera lenses are well known, but it is not so well known that he had a very perfect star-camera fixed on the tube of the 20-inch reflector, with which all objects were photographed in duplicate, during the last nine years; and it was the unvarying superiority of the

reflector plates that made him so sceptical as to much that was called nebulosity on camera plates by other observers."

The climatic conditions of Maghull did not admit of as many clear nights as an enthusiastic astronomer would desire; accordingly Roberts, after freedom from the cares of business had rendered a change of residence possible, determined to remove his observatory to some more favoured locality. He took characteristic pains to make his change effectual. He personally investigated many sites. He even went out to the West Indies to see whether he could there obtain the conditions that seemed to him best. Finally he decided to establish his observatory on Crowborough Hill, Sussex, and, as the event proved, no choice could have been more judicious.

To Crowborough the astronomical equipment was transferred in 1890, and there, with unremitting diligence, the work was carried on, so that thousands of negatives have been taken and carefully preserved as the result. Starfield, as his house at Crowborough was called, was an ideal home for an astronomer. At an eminence of 800 feet, it commands a superb view over the surrounding country. The observatory was in communication with the commodious residence, and situated in a beautiful garden. To this garden Dr. Roberts devoted much care and attention. The visitor to Starfield could not fail to be impressed by the wonderful gallery of astronomical photographs there displayed. The plates of comets, of star clusters, and, above all, of nebulæ, judiciously selected from the thousands available, formed a magnificent exhibition on the walls.

The astronomical work of Dr. Roberts at Crowborough was carried out with systematic thoroughness. The time tables, according to which the day was passed, gave to each hour its allotted task. Some hours of the morning and some of the afternoon were always set apart for astronomical work. In the early years of his career at Maghull he was himself the capable photographer of the heavens. At Crowborough he was so fortunate as to secure the skilful services of Mr. W. S. Franks as his practical photographer, and it was by the diligence of Mr. Franks, under the incessant supervision and guidance of Dr. Roberts, that the wonderful collection of Crowborough photographs has been obtained.

How diligently the work was carried on from year to year will, perhaps, be best seen by looking at the successive Annual Reports of the Council of the Royal Astronomical Society. To these Reports Dr. Roberts contributed each year an account of the work done in his observatory during the preceding year. Of these reports there are twelve. The last but one, dated February, 1903, gives a list of about seventy nebulæ which had been photographed during 1902. The

photographs were taken with the 20-inch mirror, which had been recently re-silvered, and the length of exposure was generally $1\frac{1}{2}$ hours. In this year, as in others, the principal comets which appeared were also photographed.

The last of these notable lists, dated February, 1904, contains a magnificent record of work. There are upwards of ninety entries. The great majority of the objects photographed are nebulæ, as in the former lists, but a good many clusters, or parts of the milky way, are included, and occasionally some other objects, such as the famous star (1830) Groombridge, and the comet of Borelly, in 1903.

In the words of Roberts himself he "has contributed to the Royal Astronomical Society and to 'Knowledge,' between the years 1886 and 1903, upwards of 150 photographs taken with his 20-inch reflector, each of which showed structural and other details of objects in the sky, that were previously unknown to astronomers." The last words make a great claim, but its complete justice will be admitted.

Much labour was devoted by Dr. Roberts to the design and con struction of an instrument which he called the Pantograver. The object of this instrument was to transfer, as it were, the images of stars, both in size and position, from a perishable gelatine film to an imperishable record, by engraving them on a copper plate. But this machine originated in the early years of Dr. Roberts' astronomical work, and before the time when he had fortunately decided to devote himself to the photography of nebulæ. It was at first Dr. Roberts' intention to prepare a photographic chart of the heavens on a scale twice the size of Argilander's, and with an exposure of 15 minutes for each plate, and several specimen plates were sent to the Royal Astronomical Society in 1886. After the international scheme had been formed by the Convention in Paris for the preparation of the photographic chart of the heavens on a vast scale, Roberts saw that his energies could be most effectively employed in some other direction than that of charting stars, and thus the Pantograver has had but little relation to his later work. For a description of this machine reference may be made to his paper 'On an instrument for measuring the positions and magnitudes of stars in photographs, and for engraving them upon metal plates, with illustrations of the method of using the instrument.' "Monthly Notices," vol. xlix., p. 5.

The Gold Medal of the Royal Astronomical Society was awarded to Dr. Isaac Roberts in 1895 for his photographs of star clusters and nebulæ. The address on the presentation of the medal was delivered by the President, Sir W. de W. Abney, whose profound acquaintance with the photographic arts, made the occasion one of exceptional interest. In this address Sir W. Abney says :—

"The photographs by Common of the great nebula in Orion were epoch-making in astronomical photography, and worthily was the medal bestowed on him for his classic work, and it is no disparagement of the labours of the present recipient (Roberts) if one traces in them the mark of what Common had shown to be possibilities."

Perhaps the most famous of Dr. Roberts' photographs was that of the great nebula in Andromeda. This plate it was which first fully illustrated the capabilities of photography for the representation of nebulæ. Even after the lapse of 15 years it may still be doubted whether any more beautiful representation of any celestial object has ever been produced. Of this Sir W. Abney said in the address just referred to :—

"In December, 1886, Roberts produced a photograph of the nebula in Orion with his 20-inch reflector with an exposure of 15 minutes, and almost exactly 10 years after he produced a photograph of the same object with an exposure of 81 minutes, and introduced us to nebulosities in the surrounding parts which were unsuspected before. . . . A little afterwards he produced his recently published photograph of the great nebula in Andromeda, giving an exposure of 4 hours to the plate. In this prolonged exposure we have an example of a triumph of patience and of instrumental perfection, though these qualities are exhibited in other instances as well. This beautiful object is depicted with its rings of nebulosity in great perfection, and we can correct the eye observations which had previously been made upon it. The stars in the field are beautifully sharp and round, showing that the eye as well as the instrument had to be employed throughout that long exposure to correct changes in the position of the star due to atmospheric refraction, and variation in the rate of clock-driving."

Notwithstanding all his later successes with the spiral nebulæ, Roberts always considered the Andromeda picture as his most notable achievement. In the fine portrait of him which was executed shortly before his death by his wife's sister, the favourite pupil of Rosa Bonheur, Roberts is represented resting in an arm-chair, and holding in his hand one of his memorable photographs. The plate which he chose was that of the great nebula in Andromeda, taken 15 years before. With consummate skill the artist has reproduced in an oil painting much of the delicacy and beauty which give that picture its charm.

In 1896 Dr. Roberts was one of the party who went to Vadso in the steamship "Norse King" to observe the total eclipse of that year. The eclipse itself was disappointing, but the circumstance deserves record from the fact that among those on board was Mademoiselle Dorothea Klumpke, D.Sc., of Paris Observatory, herself an earnest and distinguished worker in astronomical science. The acquaintance thus

begun had a happy issue. In 1901 Roberts married for the second time, and in this union with his fellow-traveller on the "Norse King" Isaac Roberts found not only domestic affection, but also the happiness of sympathetic co-operation in his noble work. His first wife, to whom he had been married in 1875, was Ellen Anne, daughter of Mr. Anthony Cartmel.

The chief public testimony to the value of Dr. Roberts' work is found in the facts that in 1890 he became a Fellow of the Royal Society, that in 1892 he received the honorary degree of D.Sc. from the University of Dublin on the occasion of its tercentenary, and that, as already mentioned, he received the gold medal of the Royal Astronomical Society in 1895. When he left Liverpool for Crowborough he was presented with an address signed by the Mayor of Liverpool, the leading citizens, and many scientific men connected with the University College in that city. In Crowborough he was highly respected for his vigorous independence of thought. Though he did not come prominently before the public as a politician, he held exceedingly strong views on many public questions. He was an enthusiastic Free Trader, and a sturdy opponent of the recent Education Acts.

His death took place quite suddenly on July 17, 1904. He had been working at his negatives on the very last day of his life, only a few days after he had attended the funeral of his old and valued astronomical friend, Captain Noble.

His estate of £40,000 he bequeathed for the provision of annuities to his widow and other relatives, the capital ultimately to go to the Universities of Liverpool and Wales for the foundation of scholarships.

Roberts' photographs will gather increased value as time advances. The changes in the nebulæ, if changes there be, can only be certainly ascertained by the comparison of photographs separated by long, perhaps very long, intervals of time. These magnificent plates have been bequeathed by Dr. Roberts to his widow, Dorothea Isaac Roberts. In her most capable hands astronomers know that nothing will be omitted which zeal for the advance of astronomy and affectionate reverence for the memory of the dead can suggest.

The best memorial of Isaac Roberts is to be found in his two magnificent volumes of "Celestial Photographs," which he generously distributed widely among astronomers. We conclude with an extract from the preface to Roberts' first volume in 1893, which he has himself quoted from in the preface to his later volume in 1899. The dignity of the words illustrates the character of the man as well as the importance of his work—

"It has been my aim, in publishing the photographs and descriptive matter contained in the following pages, to place data in the hands of

astronomers for the study of astronomical phenomena, which have been obtained by the aid of mechanical, manipulative, and chemical processes of the highest order at present attainable, and that such data should be, as regards the photographs, free from all personal errors.

"The photographs portray portions of the starry heavens in a form at all times available for study, and identically as they appear to an observer aided by a powerful telescope and clear sky for observing.

"Absent are the atmospheric tremors, the cold observatory, the interrupting clouds, the straining of the eyes, the numbing of the limbs, the errors in recording observations, and the many hardships incurred by our predecessors of glorious memory in their attempts to see and fathom the illimitable beyond.

"I commend the observations and the photographs herein to astronomers and students of the new astronomy."

R. S. B.

LIEUT.-GEN. C. A. McMAHON. 1830—1904.

LIEUT.-GEN. CHARLES ALEXANDER McMAHON, who died on February 21, 1904, at his residence in Nevern Square, London, was born at Highgate on the 23rd of March, 1830. By descent he was Irish, for he derived his name from a clan living in the North of Ireland, whose chief bore the title "Maghghamhna" (a bear), which became McMahon in the unpractised mouths of the seventeenth century English settlers. His grandfather took Orders in the Anglo-Irish Church, and married an English wife, but afterwards became entangled with the United Irishmen, and found it prudent to quit the country in the summer of 1797. Seeking refuge in France, he exchanged the gown for the sword, and attained the rank of captain in the Irish Legion. But his elder son Alexander, though he joined his father in France in 1802, and was educated at St. Cyr, returned to England in 1806, obtained a cadetship in the East India Company's Service, and landed at Calcutta on his sixteenth birthday. On reaching the rank of captain, he retired, and spent the rest of his life in England, where he married Miss Ann Mansell, daughter of a major in the British Army.

Their son Charles Alexander followed his father's steps, and early in 1847 obtained a commission in the 39th Madras Native Infantry. In this regiment he served for eight years, and was then transferred to the Madras Staff Corps, and from that, early in 1856, to the Punjab Commission. On this he rose to be a Commissioner, holding that office for about 14 years, and retired in 1885, his last appointment being the Commissionership of Lahore. By that time he had become a colonel in the Army, but after his return to England he rose to be major-general in 1888, and lieutenant-general in 1892. One notable episode in his Indian career illustrated his readiness and courage as a soldier, another his ability as a judge. In 1857, at the outbreak of the Mutiny, McMahon, then a lieutenant and Assistant Commissioner of Sialkot, was placed, by the illness of his superior, in charge of a large district, including a cantonment. Directly afterwards, on July 9, the native troops rose, murdered some Europeans, among them four of their officers, and, after plundering the place, decamped to join the rebels. McMahon managed to send off a hurried note by a trustworthy trooper to General Nicholson, who was leading a moveable column to Delhi, which fortunately reached him at Amritsar. Changing his line of march, he met and destroyed the main body of mutineers at Trimmoo Ghat, and restored order at Sialkot so completely that a few days later McMahon led a small force to the frontier of Kashmir, and obtained the surrender of some hundred and forty refugee rebels, most of whom were duly executed.

The other instance was in 1865, when, as Deputy Commissioner of Delhi, he had to decide a very important civil suit against the Government of India, which had been remitted by the Privy Council for trial on its merits. The plaintiffs claimed possession of the Pergannah of Badshah-Pur, with the mesne profits for about fifty years; the sum involved being estimated at a million and a-half pounds sterling. The issues were intricate, and it is no small testimony to McMahon's judicial powers that his decision was upheld, on appeal, first by the Superior Courts of the Punjaub, and then by the Privy Council in England.

He began the serious study of geology and petrology in 1871, when Commissioner of Hissar, and six years later his first important paper, a description of the Blaini Group and the central gneiss of the Simla Himalayas, was published in the "Records of the Geological Survey of India" (Vol. X). He speaks, in this, of having examined more than two hundred thin slices of rocks which, presumably, had been made with his own hands. It was followed by 'Notes of a Tour through Hangrang and Spiti,' in which he describes certain schists, the central gneiss and granite, asserting the last to be indubitably an eruptive rock, and makes some interesting remarks on glacial phenomena

and the rate of erosion of the Spiti valley. Returning home on furlough, the Lieutenant-Colonel, as he had then become, showed his thoroughness and zeal for knowledge by entering as a student at the Royal School of Mines, where he attended the lectures of Profs. Huxley, Judd, and Warington Smyth. On going back to India he applied himself with increased vigour to the problems which, as we can see from the writings just mentioned, had already engaged his attention, and the results of his work are embodied in twenty-one papers published in the "Records of the Geological Survey of India." About nine of them are petrographical; careful descriptions of the microscopic structure of various rocks, such as basalts from Bombay and Aden, or traps from Darang, Mandi, and near Dalhousie; but the majority are petrological, where the microscope is made subservient to the study of large questions, raised by his work in the mountain region about Dalhousie and Simla. He states in a paper on the geology of the former, published in Vol. XV of the "Records," that he had independently reached the conclusion for which a few English geologists were then (about 1881) contending: that, as a general rule, the extent of metamorphism affords an indication of the relative age of ancient rocks; the apparent exceptions, so far as he had seen, being due to faulting. In a later paper, 'On the Microscopic Structure of the Dalhousie Rocks,' he advances a step farther, by proving the axial gneiss of the Dhuladhar range to possess the characteristics of an igneous rock, adding that he now felt obliged to substitute the term "gneissose granite" for "granitoid gneiss" and its equivalent "central gneiss." Writing in the seventeenth volume (1884) on the microscopic structure of some Himalayan granites and gneissose granites, he shows the foliation in these rocks to be a result of fluxion in a viscid mass which is being forced through a fissure in older masses. In later papers he brings additional evidence to support this conclusion, which he expresses more fully in two communications to the "Geological Magazine" for 1887, namely, that foliation and banding in holocrystalline rocks are often the result of fluxional movement while in a viscid or even partly crystallized state; a conclusion which he was the first to demonstrate, and one very valuable at that time as a corrective to exaggerated views of the effect of pressure as an agent of metamorphism.

On returning to England, after thirty-eight years' service, McMahon settled down with his family in Nevern Square, to devote his leisure to his favourite studies. Among its fruits were four papers which appeared in the "Mineralogical Magazine" (one being an important investigation of the microchemical analysis of rock-making minerals), frequent contributions to the "Geological Magazine" and six papers

published in the "Quarterly Journal of the Geological Society." Of these, two discuss difficult questions about the nature and relations of the crystalline rocks of the Lizard; two deal with the neighbourhood of Dartmoor; and the other two, in which his son, Capt. A. H. McMahon, co-operated, are further contributions to Indian geology. He was President of the Geologists' Association in 1894–5, of the Geological Section of the British Association in 1902, and served more than once on the Council of the Geological Society, of which he was elected a Fellow in 1878. He was awarded the Lyell Medal of that Society in 1899, and in the previous year was elected a Fellow of the Royal Society. At scientific meetings he was an effective contributor to discussion, for he never rose unless he had something to say worth hearing, and was terse and lucid in expression. He exemplified the best results of a military and a judicial training, and united an inflexible integrity to great personal amiability. These qualities, intellectual and moral, made him always a most valuable member of any committee or council. From having worked with him in the study and in the field, for we co-operated in a paper on the Lizard rocks, I can testify to his thoroughness of work, his clearness of thought, and his soundness of judgment. Thus, though no heat of debate ever ruffled his uniform courtesy, he was a formidable antagonist; this he proved himself on more than one occasion, and perhaps never more than in his last contribution to the "Geological Magazine," which, though published only three months before his death, showed all his wonted grasp of his subject and power of polished satire. Yet he was then hopelessly ill and almost blind, for his eyesight began to fail him in the spring of 1902, and this was followed by a general decline in health, which ended in death on February 21, 1904.

He was twice married: in 1857 to Miss Elizabeth Head, who died in the autumn of 1866; of their children, two sons, the elder being Lieutenant-Colonel Arthur Henry McMahon, C.S.I., C.I.E., who inherits his father's love of geology, and one daughter, are living. In 1868 he married Miss Charlotte Emily Dorling, who survives him, together with a son and a daughter, and whom I have to thank for much information about my friend's family history.

T. G. B.

ROBERT McLACHLAN. 1837—1904.

ROBERT McLACHLAN was the son of Hugh McLachlan, a native of Greenock, who in early life settled in London, and was eminently successful as a chronometer maker. He resided at first near the River—but the waters of the St. Katherine's Dock now flow over the site—and afterwards at 17, Upper East Smithfield, where he died in 1855. Robert McLachlan, one of five children—three brothers and two sisters—was born at the Smithfield home on the 10th April, 1837. During the latter part of his life Hugh McLachlan had a small farm or country house in Hainault Forest, where his children spent most of their early days and were able to enjoy a country life, and it was probably there that Robert McLachlan first turned his thoughts to the study of nature.

Very little is known as to his school life beyond the fact that he was educated at Ilford, probably in a private school. He had a good knowledge of English, French and German, and was accurate in his style of writing, avoiding all redundancy of expression.

In early life he contemplated marriage, but the engagement was broken off, and soon after, in 1855, he started for a voyage to New South Wales and Shanghai; during his journey he collected plants assiduously, and his journal, as also the collections he then formed, are still in existence, the species determined and bearing their specific names. This, it is believed, was carried out with the assistance of the late Robert Brown, the well-known botanist and keeper of the Botanical Department of the British Museum. This early love for botany had to give way largely in later life to his entomological studies; but McLachlan always retained an affection for botanical science and had a good knowledge of the British flora. He delighted in his small garden and greenhouse at Lewisham, where he grew many rare or unusual plants obtained from horticultural friends. After his return from the voyage McLachlan resided with his mother at Forest Hill, and it was here that his earliest papers on Lepidoptera and Neuroptera were written. At first, as with most young people, he seems to have devoted himself to Lepidoptera, in the study of which he doubtless received much help from his friends Stainton, Knaggs Douglas, and Rye—very soon, however, he was stimulated by the writings of Dr. Hagen, to begin a special study of the group which

was to provide the chief interest of his life, viz: the Neuroptera (in the broad sense). His first paper on these insects, including a description of a new British species, appeared in the "Entomologist's Annual" for 1861; here he commends the study of the *Phryganidæ* to his fellow Lepidopterists "as tending to rectify those habits of careless and superficial examination which have gained for us the reputation of being the least scientific among Entomologists." He certainly acted up to his own recommendation, for throughout his writings, the accurate description of minute structure is a principal characteristic. The papers which had aroused McLachlan's enthusiasm for the Neuroptera were also published by Dr. Hagen in the "Entomologist's Annual," and a frequent correspondence was kept up between the two authors until the death of the latter in 1893. In the Obituary Notice which McLachlan wrote of Dr. Hagen in the "Entomologist's Monthly Magazine," he says:—"I was most emphatically his pupil. When he was in London engaged on the compilation of his Bibliotheca I met him for the first time. He took the opportunity of making an examination of the various collections of Neuroptera, and one result was a series of synopses of the British species (all excepting *Perlidæ*), published in the "Entomologist's Annuals" for several years. That on *Phryganidæ* (1859–61) attracted my attention and induced me to study these insects."

Before 1870, McLachlan had published monographs of most of the families of British Neuroptera and Pseudoneuroptera with the exception of the *Odonata*, the *Ephemeridæ* and the *Perlidæ*. The first of these had, he considered, been satisfactorily dealt with by de Selys Longchamps and Hagen. The second, that "most difficult family," to use his own words, he left to his friend A. E. Eaton; and the third, he hoped, writing in 1868, "to place on the same footing as the groups now finished," a hope destined to be unfulfilled.

About this time he set to work in earnest to collect materials for his "Monographic Revision and Synopsis of the Trichoptera of the European Fauna." This, the chief work of his life-time, appeared at intervals from 1874 to 1880, and represents an immense amount of careful investigation and diagnosis. It is illustrated by fifty-nine plates of structural detail, chiefly wing neuration and genital armatures; the figures were prepared from his own drawings made under the camera lucida, in numbers amounting to nearly 2,000. The strain of all this minute and careful work was excessive, and his eyesight never entirely recovered; in the preface (p. iii) are to be found some of the very few remarks he made on the subject of evolution, and he there points out the great value of the structure of the secondary sexual appendages in affording specific characteristics.

In addition to the above-mentioned works, papers from his pen on Exotic and British Neuroptera and other groups are to be found scattered throughout contemporary entomological literature.

The collection of Neuroptera which he formed, probably one of the largest known, is, of course, specially interesting as illustrating his various writings; he once contemplated making over his collections by deed of gift to the British Museum (Natural History), but no deed was executed, and at his death the unsigned draft was found amongst his papers. His collection of British Lepidoptera is also an extensive one, and contains many species, now rare or extinct in Britain, which were easily obtainable in his collecting days.

One of his principal interests and the well nigh absorbing enthusiasm of his later years was the conduct of the "Entomologist's Monthly Magazine," the interests of which journal he guarded with the utmost zeal, acting as an editor from its commencement in 1864, and becoming proprietor after the death of H. T. Stainton, in 1902.

During the most active part of his career McLachlan frequently travelled on the Continent, and kept up an extensive correspondence with Continental and American entomologists. How greatly his work was appreciated outside his own country is indicated by the numerous honorary positions which he held in foreign Societies.

He was a Fellow of most of our English Scientific Societies, and took an active interest in many of them. He was elected a Fellow of the Royal Society in 1877, and was appointed by the Council as a Member of the "Committee to Superintend the Printing of the Catalogue of Scientific Papers," when it was constituted in December, 1899, and he read the proofs of Vols. IX, X, XI, and XII, paying special attention to the papers on entomology. He was also a Member of the Evolution Committee to which he was appointed in December, 1898.

In the affairs of the Entomological Society of London he took a very prominent part. He was Secretary from 1868 to 1872, Treasurer from 1873 to 1875, and again from 1891 to the time of his death. He was President for the years 1885–6, a time during which the Society obtained its charter of incorporation, and his name appears on the document as the first President under the new order, John Obadiah Westwood being appointed as Honorary Life President. The Catalogue of the Society's library also owes much to his exertions. He was a very constant attendant at the Meetings, and expressed his opinions on most of the subjects brought up for discussion. Although a convinced evolutionist he rarely entered into lengthy arguments in these matters; looking upon many of the views expressed in con-

troversy on the subject as too theoretical, he preferred to devote himself to work of a more practical kind.

At one time he attended the Meetings of the Linnean Society with considerable regularity, and served on its Council. He was also present at most of the gatherings of the British Association, of which he was a Member. The Royal Horticultural Society was another body in which he took an active interest, serving for years on its Scientific Committee. All this active work was in large part abandoned during the last few years of his life. He does not appear to have been at any time actually engaged in business, but was for some years nominally a shipbroker, acting for a single ship the *Canaan*, of which vessel he, with some of his relatives, was a part owner. For a short time he had an office in the City, and until quite lately used almost daily to visit "the Jerusalem" in order to meet his old friends.

The death of his two nephews, W. J. and Hugh Wilson, one of whom for some years lived with him, was a very heavy blow, and one from which it is believed he never recovered. For several years McLachlan had suffered more or less from insomnia, causing him a good deal of anxiety, and rendering necessary the employment of special treatment; it was not, however, until last year that he showed any actual failure of power, but it then became evident to all his friends that he was gradually becoming weaker. Up to a few weeks of his death he was able to discuss matters connected with the Entomological Society and the "Entomologist's Monthly Magazine" with more or less clearness. About a fortnight before he died he had a paralytic seizure, and complete consciousness never returned.

The following is a quotation from a letter written to a friend during his last illness: "Unfortunately, with the general health the power of work gradually lessened, to my great grief; I can only look back and hope I may have done something that is useful to the present and future generations of Neuropterists."

E. S.

SIR CLEMENT LE NEVE FOSTER. 1841—1904.

CLEMENT LE NEVE FOSTER was the second son of the late Mr. Peter Le Neve Foster, who, from 1853 to 1879, acted as Secretary to the Society of Arts. Peter Le Neve Foster, who was educated at Norwich Grammar School and Trinity Hall, Cambridge, practised as a conveyancing barrister from 1836 to 1853, and during this period took a very active interest in the work of the Society of Arts—especially in the development of the infant art of photography, and in the movements which led to the inception of the Great International Exhibition of 1851. Peter Le Neve Foster was thus specially prepared and qualified to undertake the work of Secretary to the Society, a post to which he was appointed in 1853, and of which he discharged the important duties for more than a quarter of a century. Clement Le Neve Foster's mother was Georgiana Elizabeth, a daughter of the Rev. Clement Chevallier, through whom he was related to Lord Kitchener.

The subject of this notice was born at Camberwell on March 23, 1841, and his early education was obtained at the Collegiate School in that suburb. From the age of 12 to 16, however, he continued his studies at the Collége Communal of Boulogne-sur-Mer, taking his degree of Bachelor of Science in the University of France in 1857. To this education abroad may perhaps be ascribed the remarkable abilities as a linguist which Clement Le Neve Foster exhibited in after-life—abilities which proved of such great service to him in his subsequent career. Entering the School of Mines in 1857, when he was only 16 years of age, he obtained the Associateship in Mining, Metallurgy and Geology, winning also the Duke of Cornwall's Scholarship and the Edward-Forbes Medal and Prize. On leaving the London School of Mines, Clement Le Neve Foster spent a session at the famous Mining School of Freiberg, in Saxony, and then visited the chief mining centres of Germany and Hungary.

In 1860 Clement Le Neve Foster received from Sir Roderick Murchison an appointment on the Geological Survey of England and Wales, and for five years was engaged in mapping the Carboniferous rocks of Derbyshire and Yorkshire and the Wealden beds of Kent and Sussex. It was while working in this last-mentioned district that Le Neve Foster was able to make a very noteworthy contribution to geological science in the memoir, published in conjunction with a colleague upon the Geological Survey—the late William Topley—"On the Superficial Deposits of the Valley of the Medway, with Remarks

on the Denudation of the Weald." This memoir appeared in the twenty-first volume of the "Quarterly Journal of the Geological Society." The peculiar and seemingly anomalous system of drainage in the Wealden district of the south-east of England—where the rivers, instead of following what would appear to be their natural course from west to east into the North Sea, cut their way through narrow gorges in the North and South Downs and flow north and south into the Thames and the English Channel respectively—had long attracted the attention of geologists. To account for the phenomenon, Hopkins and others had maintained that the longitudinal fold of the Weald must have been accompanied by a series of transverse fractures, along which the rivers had eventually cut their courses. Murchison and Lyell maintained, however, that the main portion of the denudation of the Wealden anticlinal could only have been effected by marine agency. The publication in 1862 of Jukes' luminous memoir "On the River Valleys of the South of Ireland" had thrown doubt on these earlier conclusions of geologists, and led at the same time to a clearer recognition of the part played by subaerial and river denudation, and Jukes' views had found a zealous advocate in the late Sir Andrew Ramsay. Le Neve Foster and Topley, by a study of the nature and composition of the gravels which form terraces of the Medway Valley up to the height of over 300 feet above the existing river, were able to show that their deposition could not possibly be ascribed to marine action, but must have been due to the operation of the river and its tributaries when flowing at higher levels. Further than this, they were able to demonstrate that all the principal rivers of the Wealden area, now running northward or southward, must have begun to flow, before the east and west valleys had originated, through the wearing away of the softer or least resistant strata by subaerial action, and that, as the level of the rivers had been gradually lowered, the remarkable gorges through the North and South Downs, by which the rivers now find their outlet, had been slowly cut down.

These interesting conclusions have now been universally accepted by geologists, and it is not too much to say that the important memoir of Le Neve Foster and Topley, supporting as it did, by reference to a very well-known area, the masterly researches of Jukes in Ireland, has proved the starting point of those valuable investigations concerning the origin and development of river systems, which, commenced in this country, have been carried out with such striking results by the geologists and geographers of the United States. It is interesting to note that Le Neve Foster's share in this work had been accomplished before he reached the age of twenty-four.

In 1865 Clement Le Neve Foster resigned his post on the Geological Survey and became Lecturer to the Miners' Association of Cornwall

and Devon, the forerunner of the Mining School of Camborne. He also acted as Secretary to the Royal Cornwall Polytechnic Society. His interest in mineralogical and mining studies at this period is indicated by papers published by him in the "Geological Magazine" for 1866 upon a curious mineral vein at Roscwarne Mine, Cornwall, and upon the occurrence of molybdenite and linarite in Leicestershire and Cornwall respectively.

Early in 1868 Le Neve Foster joined an exploring expedition sent by the Khedive of Egypt to examine the mineral resources of the Sinaitic peninsula, and a joint memoir with Mr. H. Bauerman on the occurrence of celestine in the nummulitic limestone was one of the fruits of the expedition. In the summer of the same year he proceeded to Venezuela to report upon the Caratal goldfield, and the results of his study were communicated to both English and foreign scientific journals. His appointment in the following year as Engineer to the Pestarena Gold Mining Company led to a residence of three years in the Val Anzasca, Northern Italy, and to the publication of a memoir upon the amalgamation of gold ores in Italy, which appeared in various technical journals.

In 1873, Le Neve Foster returned to Cornwall as an Inspector of Mines under the Home Office, being called upon to administer the Metalliferous Mines Regulation Act, which had recently been passed. The stringency with which he carried out the provisions of the Act met with much adverse criticism, and for a time he had to encounter some unpopularity and opposition. The best defence of his action is, however, found in the circumstance that the average death rate from mine accidents was reduced from 2 per 1,000 during the first three years of his inspectorship to 1·3 per 1,000 during the last five years. While in Cornwall, he resumed his activity in connection with the educational work among the mining population, and contributed papers on geology and mineralogy to the journals of local societies. On the foundation of the Mineralogical Society, in 1876, Le Neve Foster, who had always taken the warmest interest in the study, became an original member and joined the Council, being elected the first Foreign Secretary of the Society. He contributed to the first volume of the "Mineralogical Magazine" four papers—two on new minerals and mineral localities in Cornwall and Devon, and two dealing with methods of blowpipe analysis, a subject in which he always took the keenest interest, and in which he was a recognised expert. At this same period he contributed to the "Quarterly Journal of the Geological Society" very valuable memoirs on the Haytor iron mine, on some stockworks in Cornwall, on the great flat lode south of Redruth and Camborne, and on some other tin deposits formed by the alteration of granite. All of these memoirs were characterised by that combination of profound and

exact scientific knowledge, with practical experience in the details of mining work, by which Le Neve Foster was always distinguished.

By his transfer from Cornwall to the district of North Wales, which took place in 1880, Le Neve Foster's purely scientific work was for a time interrupted. He was now called upon to advise the Government upon many questions connected with the administration of mines and upon the legislation necessary to ameliorate the condition of the miners. During the later portion of his official career he not only inspected the metalliferous mines of his own district, but also the ore and stone-quarries all over the country—his advice and assistance being called for in all cases where accidents occurred. The twenty-nine annual reports which he published in connexion with his office supply ample evidence of the zeal and intelligence with which his duties were discharged, and of the efforts in which he was constantly engaged to improve the condition and extend the educational advantages provided for the mining population. In 1895 he was called upon to commence the editing of an annual report on the mineral industries of the United Kingdom, and a comparison of their output with those of other countries. This was a work demanding great labour and powers of research, and its value was so greatly appreciated by the Government and the public generally that he was requested to continue the work after his retirement from the Inspectorship of Mines, which took place in 1901.

In 1890 a new sphere of activity was opened to Le Neve Foster, into which he threw himself with his accustomed energy. Sir Warington Smyth, the first lecturer on mining and mineralogy in De la Beche's foundation—the School of Mines at Jermyn Street—died suddenly in the summer of that year, and it was universally felt that no more suitable successor could be found than Clement Le Neve Foster. Great changes had taken place in the old mining school since the days when Le Neve Foster had listened to the inspiring lectures of his old teacher and friend Warington Smyth. The efforts of Huxley, seconded as they were by his colleagues upon the Council of the School, now incorporated with the Royal College of Science, had led to the establishment of systems of practical instruction in connection with nearly all the subjects taught in the College, and in the task of arranging similar courses of practical instruction in mining Le Neve Foster found abundant scope for his energy, knowledge, and wide experience. His acquaintance with the mines and mine-managers all over the country enabled him to make favourable arrangements for the students of the School of Mines to work underground, both in collieries and ore-mines, during their vacations, and thus obtain that direct experience in the details of mining work without which much of the theoretical instruction would have proved fruitless. In every effort to improve the teaching and further the interests of the students of

the School, in which he had himself had such a distinguished career, Le Neve Foster was indefatigable.

For fourteen years Le Neve Foster carried on at the same time the instruction of the students of the School of Mines in mining and his work at the Home Office. Nothing but wonderfully methodical habits, combined with unflagging energy and the vigorous health which had always been his great characteristics, could have enabled him to cope with the amount of work which he was able to accomplish during this period. Although he had attained, as we have seen, the full measure of his powers at a remarkably early age, yet the manner in which he retained his capacity for work was no less noteworthy. His personal appearance bore striking testimony to this wonderful vitality, for up to and even beyond middle age he retained the appearance of juvenility. The freshness and alertness of his mind, too, were conspicuous up to the last, and his eagerness in all he undertook was, like his personal appearance, almost boyish.

But in 1897 an event occurred which was to cause a serious interruption to this energetic career, and eventually to bring it to an untimely end. In that year an underground fire in the lead mine of Snaefell, in the Isle of Man, accompanied by a derangement of machinery by which the movements of the cage in the shaft were controlled, led to the entombment and death of a number of miners. Le Neve Foster, in his capacity as Inspector of Mines for the district, determined to undertake a personal investigation concerning the cause of the accident. Though he managed to descend the shaft safely at the head of an exploring party, return appeared to be hopelessly cut off by the jamming of the cage. It was very characteristic of him that, while undergoing the process of slow poisoning by the carbon monoxide which had been generated by the fire, he, nevertheless, when escape seemed utterly hopeless, had the presence of mind to take out his pocket-book and make a series of entries as to his sensations, for the benefit of medical men and chemists after his death. These notes, were interspersed with touching messages to his wife and children, and afford a striking evidence of his devotion to science, as well as to his coolness and presence of mind in the face of danger.

Although succour arrived in time to prevent an immediately fatal termination to the accident, and he, with the other unconscious victims, was brought to the surface, Le Neve Foster never recovered from the cardiac injury sustained during the process of gradual suffocation. For nearly a year he was incapable of engaging in any work, and even when partial restoration to health took place, it was only by the exercise of the greatest care that he could continue his accustomed labours. In 1901 he took advantage of the opportunity afforded by his attaining the age of sixty to retire from his more exacting duties

at the Home Office, though he still devoted a large part of his time with undiminished zeal to the duties of his chair at the Royal School of Mines. On April 19, 1904, after a short illness, from which he rallied several times, he at last succumbed to the effects of the Snaefell accident, passing away at the age of sixty-three.

Le Neve Foster's career was a striking illustration of the value of a sound scientific training, coupled with a love of scientific research, to one who devoted the greater part of his life to the service of the Government. As the author of numerous reports, he was able to supply the responsible authorities with the most valuable information concerning mines and miners in this country. His advice upon all questions connected with the mining profession, and on the legislation connected with it, was constantly sought by, and freely given to, his official chiefs. He served upon various departmental committees—on mineral statistics, on open quarries, on the slate mines of Merionethshire, and upon the explosives used in mines. He was a member of the Royal Commissions for the Chicago and St. Louis Exhibitions, and was, at the time of his death, a very active member of the second Royal Commission on Coal Supply. He acted as a juror at the Inventions Exhibition in 1885, and also at the Paris Exhibitions of 1867, 1878, 1889 and 1900, as well as at some minor exhibitions. His great public services abroad and at home were recognised by his being created a Knight of the Legion of Honour in 1889, while the distinction of knighthood was conferred upon him in 1903 by His Majesty King Edward the Seventh.

In spite of his official and professional engagements, Le Neve Foster found time to undertake a considerable amount of literary work. In 1867 he published a translation from the Dutch of P. von Diest's work on the tin deposits of Banca, and, in 1876, he translated from the French, with the aid of Mr. W. Galloway, Callon's "Lectures on Mining."

The article on mining in the "Encyclopædia Britannica" was written by Le Neve Foster, and, in addition to this, he found time to prepare a systematic treatise, the first on the subject published in England, on "Ore and Stone Mining," of which a fifth edition appeared at the time of his death; he also issued, at the commencement of the present year, a small volume on "Mining and Quarrying," which promises to be of the greatest service to students. His great literary activity, as well as his work as a teacher, was facilitated by the methodical manner in which he pursued his studies. He left behind him many hundreds of volumes and portfolios filled with extracts and cuttings from books, magazines and newspapers, relating to his own pursuits.

Clement Le Neve Foster early in his career became associated with the University of London, firstly as a Bachelor of Arts, and subse-

quently as a Doctor of Science. At the time of his death he was rendering valuable service to the University as Chairman of the Board of Studies in Mining and Metallurgy, and as a member of the Board of Studies in Geology. He was a Fellow of both the Geological and Mineralogical Societies, and rendered useful assistance to the infant Institution of Mining and Metallurgy, in which so many of his old fellow students and pupils were active members. In 1892 the value of Le Neve Foster's labours, alike in pure and applied science, was recognised by his election into the Royal Society.

Clement Le Neve Foster married, in 1872, Sophia Chevallier, the second daughter of the late Arthur F. Tompson, of Belton, Suffolk; he leaves a widow, a son (now a mathematical master at Eton College), and two daughters.

J. W. J.

JOSEPH DAVID EVERETT. 1831—1904.

JOSEPH DAVID EVERETT was born at Rushmere, Suffolk, in 1831. His younger brother, R. Lacey Everett, was for some years M.P. for a division of Suffolk, and his sister is a well-known Ipswich philanthropist. They were, on their father's side, descended from landed gentry of Essex and Suffolk, interested in politics, and were related to Laceys and Unwins; through their mother, Elizabeth Garwood, they were connected with persons of scientific and literary eminence; her brother was Rector of Battersea; Dr. Percy, F.R.S., was her cousin.

His home was happy, and a healthy boyhood near the sea made him very hardy and indifferent to exposure. At school he was eager and industrious; he wrote verses, was a zealous member of a debating society, and invented a geometrical puzzle. Charles Spurgeon, afterwards so famous as a preacher, was one of his later school acquaintances. There were eight other children, and there had been losses through agricultural depression, so that he became mathematical master (1850–54) in a school at Totteridge, although he would have greatly preferred to go to a university. I. Todhunter, F.R.S., had once been a master in this school, and about this time Thomas Chinnery (afterwards editor of "The Times") was a master. Sir R. Strachey, F.R.S., and some of his brothers, J. F. Cheetham, M.P., and Prof. Carey Foster, F.R.S., were pupils. Prof. Foster writes: "Games were not then so prominent or organised a business in schools as they are now, but Everett

was great at cricket, and soon became popular for his vigorous bowling. I don't remember very much about his teaching, except that he lent me De Morgan's 'Arithmetic' to read, which was quite a revelation in those days, and the fact proves that Everett had his eyes open for improved and rational methods, and did not content himself with merely following routine."

His father had no sympathy with his wish for a university education, but the son saved money, and, by hard work, gained a scholarship, entering Glasgow University in 1854. He took his M.A. in 1857 with first honours in Mathematics and Natural Philosophy, and second honours in Classics and Mental Philosophy. His intention had been to enter the ministry, but he gave up this idea, and became, for a short time, Secretary of the Meteorological Society, Edinburgh.

In 1859 he was appointed Professor of Mathematics in Windsor College, Nova Scotia, where he started astronomical and meteorological observations. He married the sister of a college friend, the Rev. J. G. Fraser, D.D., in 1862. Feeling the isolation of his position, he resigned his professorship in 1864, and became assistant to Prof. Blackburn, of Glasgow. He did important experimental work at this time in Lord Kelvin's laboratory, and was elected a Fellow of the Royal Society of Edinburgh. He was appointed to the professorship of Natural Philosophy in Queen's College, Belfast, in 1867, and remained there till 1897, when he retired at the age of 66. During the thirty years of his professorship many persons who afterwards attained considerable eminence were among his pupils. While at Belfast, besides his duties to students and the interests of local societies, he interested himself mostly in the work of Committees of the British Association and the writing and preparation of new editions of his books. From 1898, until he died, he lived with his wife and family at Ealing. Here, with his daughter Alice, he translated Dr. Hovestadt's book on Jena glass and its scientific applications. Perhaps Optics was his favourite study.

He greatly enjoyed his life in London, as he could often meet men who had the same interests as his own, and, indeed, he almost seemed to become more vigorous, and to be in better health as he got older. In the months preceding his death he read papers at the Royal, the Physical, the Geographical, and the Microscopical Societies. He did not much care for theatres or light literature. He went regularly to church, but his religious views were liberal. He was of gentle temper, and never jealous. His mind was very concentrative, and was always logical and unemotional, and free from prejudices. There was no slackness or loose-endedness about him either physically or intellectually. He liked to work in a cold, bare, well-ventilated room,

without curtains, and seldom sat in an easy chair. He practised bicycling continually from such an early date as 1868. In his later years he took to golf with some eagerness. Shorthand was one of his hobbies; he introduced a system of his own, and published several books about it, one when he was at Totteridge.

A great many scientific papers were "referred" to him for criticism, more particularly after his retirement, and he was always willing to do such work. He acted as "expert" in revising mathematical and physical slips for the Royal Society's Catalogue of Scientific Papers, his daughter having for some time before been engaged on the work under George Griffith.

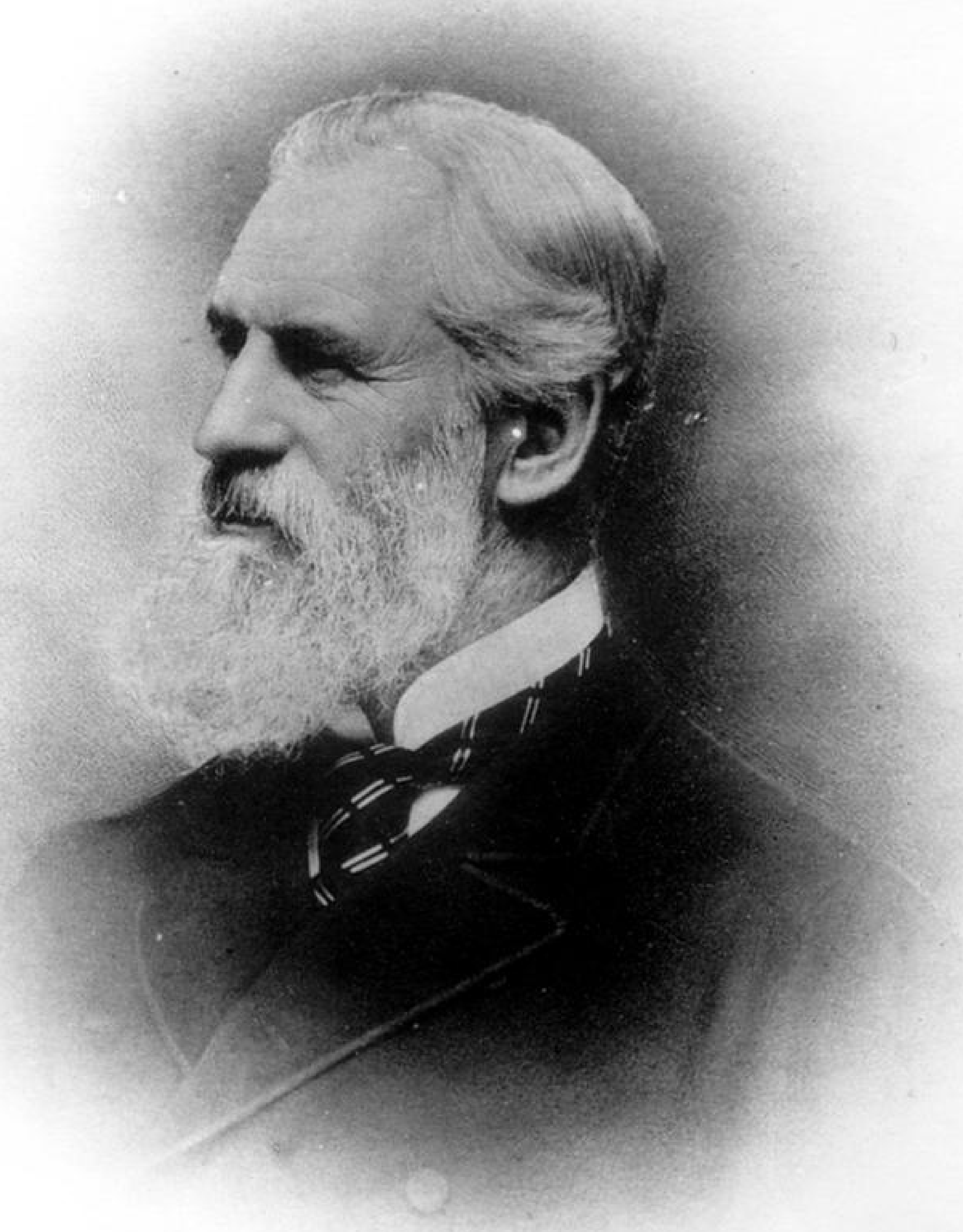
Prof. Everett remained Secretary of the Underground Temperature Committee of the British Association from its appointment in 1867, and drafted twenty-two reports, which have been published. A summary of the first fifteen was published in 1882. In 1871 he moved the appointment of a British Association Committee "for the Selection and Nomenclature of Dynamical and Electrical Units," of which he became Secretary, and in 1873 he presented a report recommending the C.G.S. system, and introducing the names *Dyne* and *Erg.* In 1875, under the auspices of the Physical Society, he published his book (subsequently enlarged, and of many editions) on Units, which was very useful in making these units well known. This book is truly a remarkable performance. It is difficult to think of any other author who would not have made it a dry catalogue, but Everett made it interesting reading, although what is most characteristic about the book is its concise precision of statement. Like everything else done by the author, everything is finished up, there are no loose ends. The work involved in the reduction of so many quantities to their equivalents in C.G.S. units was very great. Every reader feels that he may depend implicitly upon the accuracy of all the results, and this is a matter of very great consequence. It has been translated into Russian, German, French, Polish, Italian, and other languages. In 1881 the C.G.S. units were adopted by the International Congress of Electricians at Paris. He became a Fellow of the Royal Society in 1879.

His translation of Deschanel's "Physics," 1869–72, became, with additions and alterations in this and many subsequent editions, almost his own book. It has been, and still is, a valuable text-book. In 1901 the electrical portion of this was re-written. Other books, in addition to those already mentioned, were:—"An Elementary Text-Book of Physics," 1877; "Vibratory Motion and Sound," 1882; "Outlines of Natural Philosophy," 1885. He wrote the article on Interpolation in the "Encyclopædia Britannica," 1902–3. From the reading of his paper

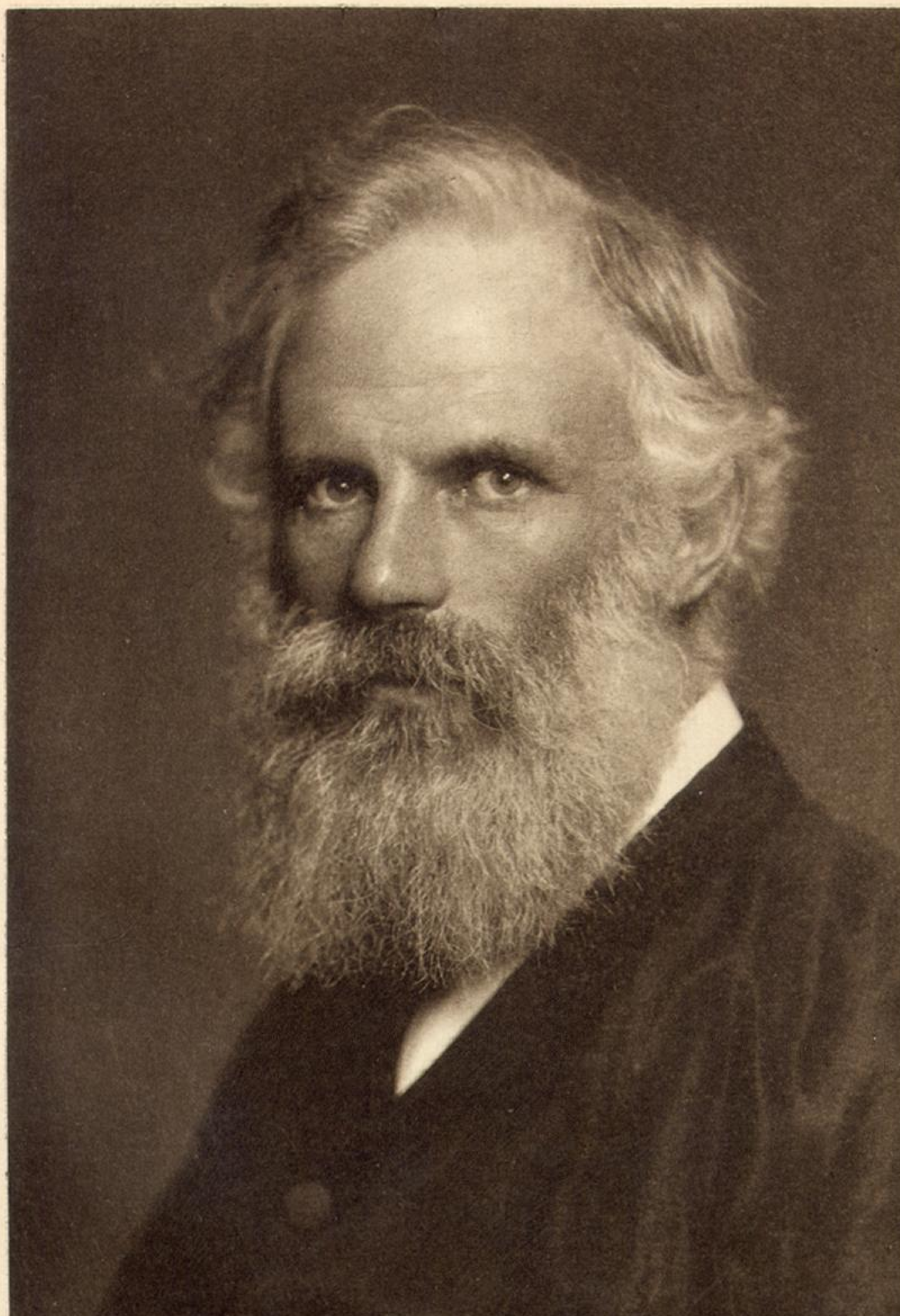
'On the Philosophy of Teaching or Psychology' before the Literary and Philosophical Society of the University of Glasgow, in 1858, until he died, he published a great number of investigations, the titles of thirty-three of them (previous to 1883) being given in the Royal Society's Catalogue. Most of these were published in the "Philosophical Magazine" or the reports of the British Association. The reduction of observations of deep-sunk thermometers will be found in "Philosophical Transactions," 1860. The results of his experiments on torsion and flexure were published in three papers, "Philosophical Transactions," 1866–7–8. 'Observations of Atmospheric Electricity at Kew and Nova Scotia' was published in "Philosophical Transactions," 1867. Three of the papers are in "Transactions," Royal Society, Edinburgh, and five in the "Proceedings," Royal Society, London. In 1866 he published a new Proportion Table consisting of two cardboard sheets, forming what is equivalent to a very long slide rule. After 1883 he published about as many papers as are mentioned in the Catalogue. A paper on 'Geometrical Illustrations of the Theory of Rent' appeared in the Royal Statistical Society's "Journal" in 1900. Some investigations of the algebra of difference tables in the "Quarterly Journal of Mathematics" were followed by the discovery of a new and very useful interpolation formula, an account of which was published by request of the Institute of Actuaries in their Journal. He took much interest in the Meetings of the Physical Society, of which he was Vice-President, and many of his later papers were read there. During his last days he was engaged in correcting the proofs of the evidence he had given before the Royal Commission on Coal Supplies, mainly dealing with questions of underground temperature.

From 1868 until he died he made few experimental investigations, but he published many papers in which he helped to elucidate and draw conclusions from the results obtained experimentally by others. He invented or simplified methods of calculation. He made no great discovery, but his work did much to connect and make clear the great discoveries of his time.

J. P.



W. H. Flower



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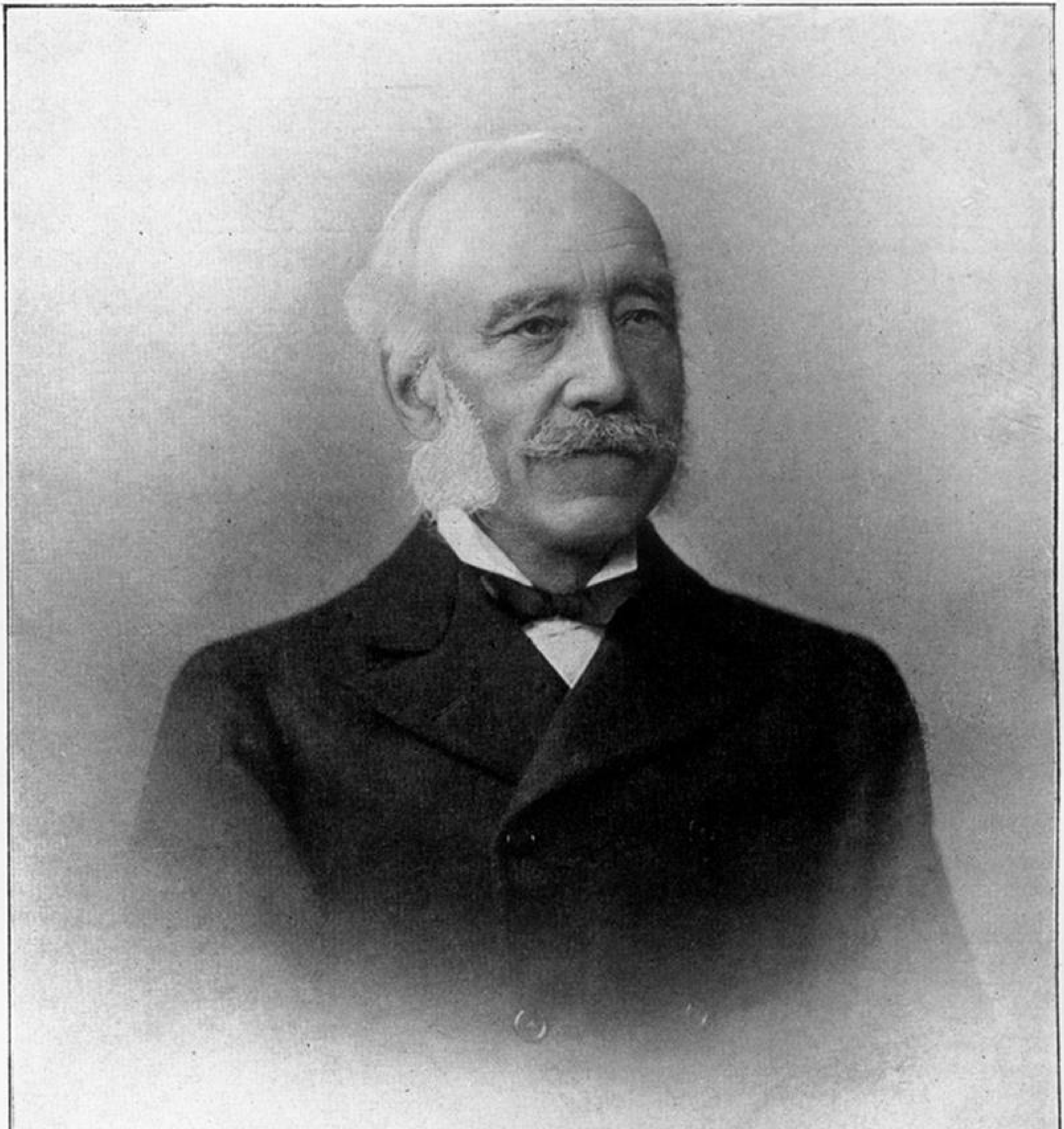

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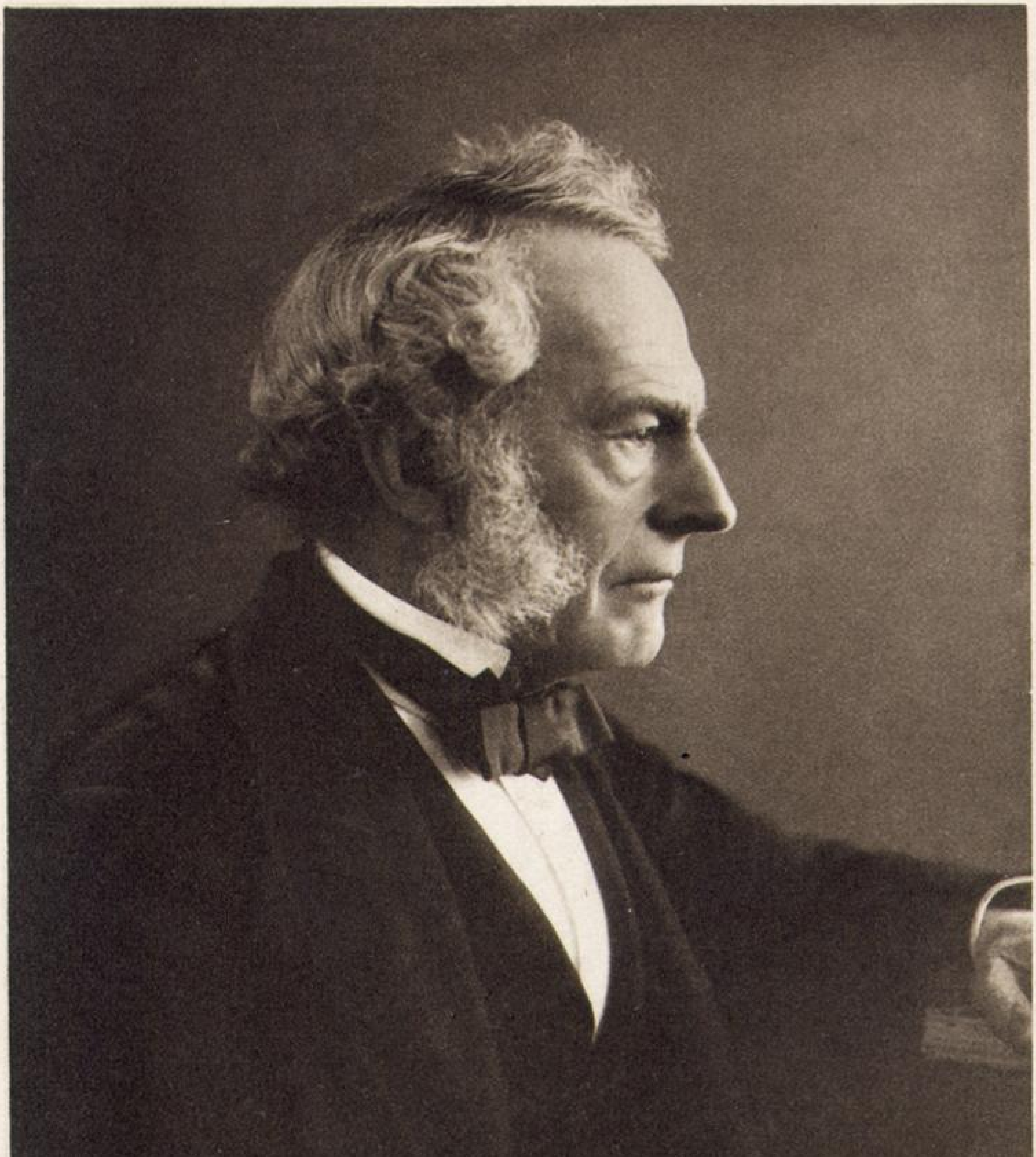

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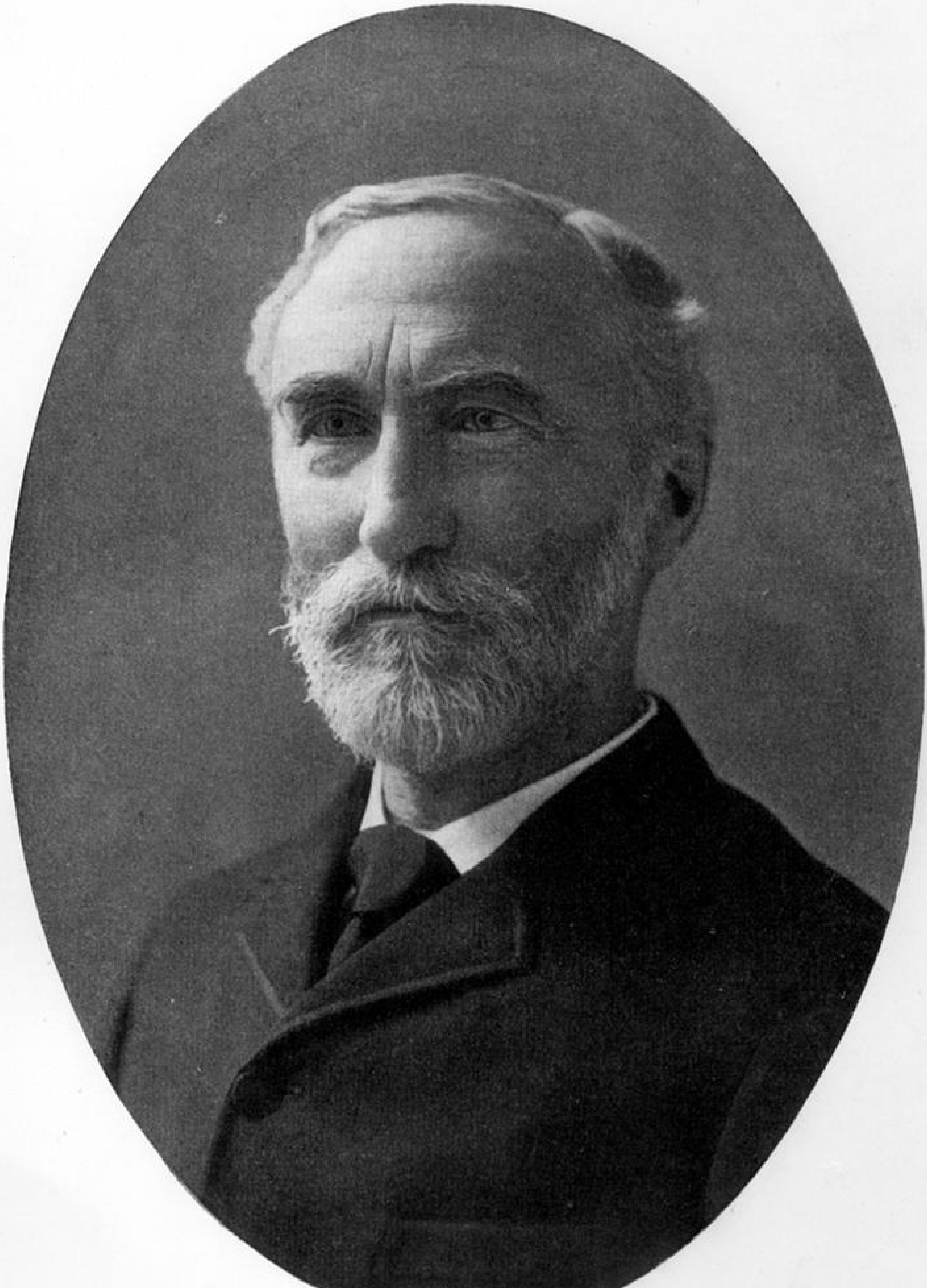
Henry Augustus Rowland.



Josiah Willard Gibbs.

Salisbury