the charm of his personal influence. Throughout his long tenure of the chair of Natural Philosophy, he has carried lightly like a flower the weight of honour which the scientific world has united to render to him. He has remained ever the same kind friend of his students, and his interest in them, old and young, and in every scientific worker, has found many quietly sympathetic modes of expression. The enthusiastic testimony to his pre-eminence as a scientific man, and to his admirable personal qualities, which was borne by the whole world at the magnificent celebration last June, will not soon be forgotten by those who had the privilege of taking part in that great ceremonial: it was an emphatic tribute to the greatness of the part which the Physical Laboratory at Glasgow has played in science during the last fifty years.

A. GRAY.

JAMES JOSEPH SYLVESTER.

HE is dead, and it becomes a sad duty to give a brief account of his long life and great work.

Born in London September 3, 1814, he was the youngest but one of seven children of Abraham Joseph Sylvester. He was the last survivor. Three sisters lived for many years at Norwood, and of his three brothers two, Frederick and Joseph, lived for the most part in America, whilst George resided at Worcester.

He obtained his early education at private schools in London; thence he went to the Liverpool Institution, and in 1837 graduated at St. John's College, Cambridge, as Second Wrangler. The first five names in the Mathematical Tripos of the year are Griffin, Sylvester, Brumell, Green, Gregory. It is astonishing to think that Green, of immortal memory, has been dead for nearly fifty years! Sylvester was keenly disappointed at his failure to be senior of the year. He was always of an excitable disposition, and it is currently reported that, on hearing the result of the examination, he was much agitated. Being of the Jewish persuasion, he was unable to take his degree at Cambridge, but later he obtained a degree at the University of Dublin. On leaving Cambridge he at once commenced the long series of mathematical papers, which he was to contribute to scientific periodicals all over the world, by the publication, in vol. xi. of the *Philosophical Magagine*, of an analytical development of Fresnel's optical theory of crystals.

This was followed by some articles upon subjects of applied mathematics, and it was not until 1839 that he brought his intellect to bear upon the analysis of continuous and of discontinuous quantity, departments of pure mathematics which well-nigh monopolised his attention for the remainder of his life. He was appointed Professor of Natural Philosophy at University College, London, and later on held the post of Professor of Mathematics in the University of Virginia. He returned to England in the year 1845, and the first period of his scientific career may be said to have closed. He had published some thirty papers, and was already well known in both hemispheres as an original and imaginative man of science. The subjects dealt with comprise "Dialytic Method of Algebraical Elimination," "Sturm's Functions," "Criteria for Determining the Roots of Numerical Equations," "The Calculus of Forms" (afterwards known as the "Theory of Invariants"), "The Equation in Integers $Ax^3 + By^3 + Cz^3 = Dxyz$." The latter problem was a favourite subject of thought throughout his life, and the first problem in the theory of numbers that he attacked. The theory of invariants sprang into existence under the strong hand of Cayley, but that it emerged finally a complete work of art, for the admiration of future generations of mathematicians, was largely owing to the flashes of inspiration with which Sylvester's intellect illuminated it. The nomenclature of the theory is almost entirely due to him. The words "invariant," "covariant," "Hessian," "discriminant," "contravariant," "combinants," "commutant," "concomitant," are a few of those introduced by him at this time, which have been part of the stock-in-trade of mathematicians ever since.

A beautiful theory of the rotation of a rigid body about a fixed point, after Poinsot, should be mentioned. It is one of the few papers that he wrote on dynamics.

For ten years after his return from Virginia he was occupied with a firm of actuaries. He founded the Law Reversionary Interest Society, and also accomplished a considerable amount of mathematical research. In 1853 appeared his first important memoir in the *Philosophical Transactions* of the Royal Society, bearing the title, "On a theory of the syzygetic relations of the rational integral functions, comprising an application to the theory of Sturm's functions and that of the greatest algebraical common measure." This is a masterly exposition, covering 170 quarto pages.

In 1855 he was appointed Professor of Mathematics at the Royal Military Academy, Woolwich. This was a great relief, as the work of an actuary was manifestly unsuitable, and had indeed been most distasteful to him. He held this professorship for fifteen years. It was a time of great activity. Year by year his fame increased, and recognition by foreign academies was liberally bestowed. In addition to continual work at the theory of invariants, he laboured at some of the most difficult questions in the theory of numbers.

Cayley had reduced the problem of invariant enumeration to that of the partition of numbers. Sylvester may be said to have revolutionised this part of mathematics by giving a complete analytical solution of the problem, which was in effect to enumerate the solutions in positive integers of the indeterminate equation—

$$ax + by + cz \ldots + ld = m$$

Thereafter he attacked the similar problem connected with two such simultaneous equations (known to Euler as the Problem of the Virgins), and was partially and considerably successful. In June 1859, he delivered a series of seven lectures on compound partition in general at King's College, London. The outlines of these lectures, printed at the time for distribution amongst his audience, are now being published for the first time by the London Mathematical Society. He was assisted in the preparation of these lectures by Captain (now Sir Andrew) Noble, with whom from that time forth he was in sympathetic friendship.

The year 1864 may be regarded as the time of his greatest intellectual achievement, which caused him to be considered as one of the foremost of living mathematicians. On April 7, 1864, he read a paper before the Royal Society of London, bearing the title "Algebraical Researches, containing a disquisition on Newton's rule for the discovery of imaginary roots, and an allied rule applicable to a particular class of equations, together with a complete invariantive determination of the character of the roots of the general equation of the fifth degree, &c." In the "Arithmetica Universalis," Newton gave a rule for discovering an inferior limit to the number of imaginary roots in an equation of any degree, but without demonstration. Neither did he give any indication of the mental process by which he was led to conjecture the truth of the rule, nor did he set forth the evidence upon which it rests. For years the question of proving or disproving the rule had been a crux of the science. Euler, Waring, Maclaurin and Campbell were amongst those who sought in vain to unravel the mystery. The only step that had been gained was to show that if *any* negative terms occur in the quadratic elements involved in the statement, there must be *some* imaginary roots. This, however, was not a great step,

as a slight consideration renders it apparent. Sylvester, in the paper quoted, established the validity of the rule for algebraical equations as far as the fifth degree inclusive. The method employed was that of "infinitesimal substitution," which he himself initiated, and had previously employed in an essay, "On the Theory of Forms," in the *Cambridge and Dublin Mathematical Journal*. It proceeded upon the principle that every finite linear substitution may be regarded as the result of an indefinite number of simple and separate infinitesimal variations impressed upon the variables. He also discussed the probability of the specific superior limit to the number of real roots in a superlinear equation equalling any assigned integer. This valuable memoir contained only a small instalment of the desired result. It was not till the following year—1865—that he fully established and generalised the conjectured theorem of Newton. On June 19, he communicated the substance of his discoveries to the Mathematical Society of London, Prof. de Morgan being in the chair as its first president; and on the following June 28 he gave a public lecture in King's College, London, taking as his title, "On an elementary proof and generalisation of Sir Isaac Newton's hitherto undemonstrated rule for the discovery of imaginary roots." Sylvester's fame with posterity will, perhaps, be principally associated with this great intellectual triumph. It may be observed that, subsequent to the demonstration, Dr. J. R. Young claimed to have proved Newton's rule twenty years before. Sylvester contested this assertion in a characteristic manner, and mathematicians are, I think, in agreement that he showed it to be without basis. He always wrote well and with considerable power of expression; but, perhaps, he was strongest when attempting to demolish any one who questioned or denied his claim to priority in a particular mathematical discovery. In the case in point he wrote: "It is such stuff as dreams are made of, and culminating as it does in a palpable *petitio principii* does not need a detailed refutation at the hands of the author of this lecture. It is not by such vague rhetorical processes, but by quite a different kind of mental toil, that the truths of science are won, or a way opened to the inner recesses of the reason."

When the British Association for the Advancement of Science met at Exeter, in 1869, Sylvester was the President of the Mathematical and Physical Section. Huxley had recently written in *Macmillan's Magazine*: "Mathematical training is almost purely deductive. The mathematician starts with a few simple propositions the proof of which is so obvious that they are called self-evident, and the rest of his work consists of subtle deductions from them"; and again, in the *Fortnightly Review*: "Mathematics is that study which knows nothing of observation, nothing of experiment, nothing of induction, nothing of causation." It may be safely said that any man engaged constantly in mathematical research would find no difficulty in refuting these statements to the satisfaction of any representative body of scientific men. Sylvester devoted a considerable portion of his address to the Section to contesting Huxley's statements, and put in a powerful and eloquent plea for mathematics as being a science of observation and experiment, and as affording a boundless scope for the exercise of the highest efforts of imagination and invention. Huxley, I believe, made no reply; and I think there can be no doubt that, like many other remarkable men in other branches of science, he had no conception of the real nature of the life-work of mathematicians of the high order to which Sylvester belonged. Amongst other matters in his address, he remarks upon the extraordinary longevity of the masters of mathematics. Amongst these long-lived ones he himself now takes an honourable place.

He left Woolwich (for years he occasionally wrote from his house on the Common, over the *nom de plume* "Lani Vicencis") in 1870, and for some years was without a professorship. During this time he was much interested in the problems of link-motion and conversion of motion generally. He wrote several valuable papers, and invented the skew pantigraph. The title of one of his papers of this period is characteristic—"Mode of construction and properties of a new sort of lady's fan, and on the expression of the curves generated by any given system whatever of link work under the form of an irreducible determinant."

He gave a Friday evening lecture at the Royal Institution, entitled "On Recent Discoveries in Mechanical Conversion of Motion."

His acceptance, in the year 1875, of an invitation to become the first Professor of Mathematics in the new Johns Hopkins University at Baltimore, in Maryland, may be regarded as concluding the second period of his career. He could hardly expect to further increase his reputation, which was extraordinarily high, and most of the honours that can fall to the lot of a scientific man had long been in his possession.

In Baltimore he soon founded the *American Journal of Mathematics*, and was surrounded by a knot of enthusiastic students, whose researches he was able to influence, and in some cases to entirely direct. His final investigations in the theory of algebraic invariants, various questions in diophantine analysis, the constructive theory of partitions, the theory of universal algebra, and the commencement of his researches on differential invariants, were principally the outcome of his residence in Baltimore. He was assisted, followed up, and frequently also inspired by his students in an ideal manner. Perhaps the most permanent impress he left on the path of American research was in the subject of universal algebra, the vigorous offspring of Cayley's memoir, of 1858, on matrices. He established the nomenclature of the subject and surveyed the unknown country. He showed the connection between linear transformation and quaternions, and further arrived easily at a generalisation of quaternions. Since then Taber, Metzler, and others in the New World, have made valuable additions to the theory.

In 1883 he was elected to succeed Henry J. Stephen Smith in the chair of the Savilian Professorship of Geometry at Oxford. His inaugural lecture was on the subject of differential invariants, termed by him reciprocants. This work was extensive and important, and its elaboration, with the able assistance of James Hammond, was the last valuable contribution he made to mathematics. With increasing age infirmities came upon him. He suffered from partial loss of sight and memory, and in 1892 he obtained permanent leave from his duties, and the University appointed a deputy professor.

Henceforth he lived for the most part in London, and was a familiar figure in the Athenæum Club, but he was never in good health. At intervals he would go down to Tunbridge Wells and live at the Spa Hotel, but he did no mathematical work, and his frame of mind was not happy. Early in 1896, his condition caused alarm to his friends. In August he quite suddenly became again interested in mathematical subjects, and this appeared to make him calmer and happier. On February 26, whilst working at the theory of numbers, he had a paralytic stroke and never spoke again. He died peacefully at 3.30 a.m. on Monday, March 15, 1897, at 5 Hertford Street, Mayfair.

His work was not so voluminous as that of many of his great contemporaries. It may amount to about 1250 octavo pages and about 1550 quarto pages. Its quality, however, is of a very high order, as he always preferred to labour at difficult questions; problems which for centuries have been a challenge to the human intellect

had an especial attraction for him. His last thoughts were concerning the distribution of the prime numbers; the excellent paper in which he contracted Tchebycheff's limits was a source of great satisfaction to him, and shortly before he died he was hopeful of being able to prove the Goldbach-Euler conjecture that every even number can be partitioned into two primes; but in this he was not successful, although he was able to narrow the issue, and to give a more precise statement of the supposed theorem. At one time he was interested in the construction of tessellated pavements; one anallagmatic design was, through the influence of his friend Colonel Yelverton, put down in the hall of the Junior United Service Club in Charles Street, Haymarket. Some years ago it was unfortunately removed whilst the hall was undergoing repair.

His writings are flowery and eloquent. He was able to make the dullest subject bright, fresh, and interesting. His enthusiasm is evident in every line. He would get quite close up to his subject, so that everything else looked small in comparison, and for the time would think and make others think that the world contained no finer matter for contemplation. His handwriting was bad, and a trouble to his printers. His papers were finished with difficulty. No sooner was the manuscript in the editor's hands than alterations, corrections, ameliorations and generalisations would suggest themselves to his mind, and every post would carry further directions to the editors and printers. His usual custom was to send early notice of his discoveries to the Academy of Sciences in Paris. Subordinate theorems he would despatch at once to the *Educational Times*. He frequently also made announcements in the columns of NATURE. He gave so many names to mathematics that he used playfully to speak of himself as the Mathematical Adam. It has been remarked by Prof. Forsyth that he drew almost entirely upon Latin for new names, whilst Cayley as invariably drew upon Greek. In 1870 he published "The Laws of Verse," dedicating it to Matthew Arnold. The composition of sonnets, both in English and Latin, was a relaxation that he much enjoyed; these have been, and no doubt will be, criticised in other places.

He was fond of billiards, whist and chess. He liked occasionally going into the society of ladies, but was never married.

He appears in the series of portraits of Scientific Worthies for the year 1889, to the accompaniment of a sympathetic notice from the pen of Cayley. His portrait in oils, by Elmslie, was exhibited in the Royal Academy a few years ago, and now hangs in the hall of St. John's College, Cambridge. His physiognomy was striking, never failing to impress deeply at a first meeting. Latterly his appearance was venerable and patriarchal.

In this short notice justice cannot be done to his character. His temper was somewhat quick on occasions, but he never cherished angry feelings beyond a very short time; he was anxious to forget and forgive. Only those who understood him were aware that anger or displeasure was with him a transient phenomenon, and that charitableness of feeling and kindness of heart were characteristics deeply engraved upon his nature. To younger men he was sympathetic and generous.

The revival of the mathematical reputation of England, dating from the Queen's accession to the throne, is to a large degree due to his genius; and those who were present on March 19, at the simple, yet impressive ceremony at the Jewish cemetery at Dalston, must have realised that one of the giants of the Victorian era had been laid to rest. The Royal Society and the London Mathematical Society were represented at the funeral by Prof. Michael Foster, Sec.R.S., Major MacMahon, R.A., F.R.S., Prof. Forsyth, F.R.S., Prof. Elliott, F.R.S., Dr. Hobson, F.R.S., Prof. Greenhill, F.R.S., Mr. A. B. Kempe, F.R.S., and Mr. A. H. Love, F.R.S. There were also present Prof. Turner and the Sub-Warden of New College, Oxford.

P. A. MACMAHON.

NOTES

A MEETING of Presidents of various scientific societies in London was recently convened by the President and Officers of the Royal Society, to consider whether any, and if so what, steps should be taken to commemorate the sixtieth year of Her Majesty's reign. It was unanimously resolved—"That a fund to be called the Victoria Research Fund be established, to be administered by representatives of the various scientific societies, for the encouragement of research in all branches of science." The President of the Royal Society has communicated this resolution to the scientific societies, with a letter asking whether support would be given to it.

AT the recent anniversary meeting of the Royal Irish Academy, Prof. Albert von Kölliker and M. A. Michel Lévy were elected honorary members in the Section of Science.

THE subject of the Croonian Lecture to be delivered at the Royal Society on Thursday next, by Prof. C. S. Sherrington, is "The Mammalian Spinal Cord as an Organ of Reflex Action."

THREE sculptors—Lessing, Hertert, and Janensch—have been selected from the list of those who made application to execute the statue of Helmholtz for the Helmholtz Memorial Committee. Which of the three will be chosen to carry out the work is not yet known. The monument will stand between the statues of the two Humboldts, in the front grounds of the University of Berlin.

WE much regret to announce the death of M. Antoine T. d'Abbadie, formerly president of the Paris Academy of Sciences. In 1893 M. d'Abbadie bequeathed to the Academy, subject to a life-interest to his wife, the Abbadia estate in the Pyrenees, having an annual revenue of twenty thousand francs, and shares in the Bank of France representing an annual income of fifteen thousand francs. He published several important works on geographical exploration and geodesy, and was sent by the Academy to St. Domingo in 1882 to observe the eclipse of the sun.

THE following are the names of the members of the British Association who have been nominated by the Council as presidents of the different Sections at the forthcoming meeting at Toronto:—(A) Mathematical and Physical Science, Prof. A. R. Forsyth, F.R.S.; (B) Chemistry, Prof. W. Ramsay, F.R.S.; (C) Geology, Dr. G. M. Dawson, C.M.G., F.R.S.; (D) Zoology, Prof. L. C. Miall, F.R.S.; (E) Geography, Mr. J. Scott Keltie; (F) Economic Science and Statistics, Prof. E. C. K. Gonner; (G) Mechanical Science, Mr. G. F. Deacon; (H) Anthropology, Prof. Sir W. Turner, F.R.S.; (I) Physiology, Prof. M. Foster, Sec.R.S.; (K) Botany, Prof. H. Marshall Ward, F.R.S. The two evening discourses will be delivered by Prof. Roberts-Austen, C.B., F.R.S., and by Prof. John Milne, F.R.S.

MR. MORRIS K. JESUP, president of the American Museum of Natural History, is fitting out an elaborate anthropological expedition to undertake a seven years' tour for the study of prehistoric man in all parts of the world, at a cost estimated as over sixty thousand dollars. It will be the most elaborate and best-equipped expedition ever sent out in the interests of anthropology. Mr. Jesup has already done much for scientific research. Several