

he affords a conspicuous example, in his own line, of the benefits that may be conferred on mankind by rightly directed thought, even when unaided by acquired learning. He followed the religion of his country, without associating himself with theological controversies; and his numerous acts of charity and benevolence were bestowed with the utmost care that the giver should remain unknown.

Mr. Appold was afflicted with a painful disease for the last few years of his life, which he bore with heroic fortitude. He was suddenly, however, seized with internal hæmorrhage at Clifton, when he met his death with that calm resignation which marks the true philosopher. To the honour of the inhabitants of the parish in which he lived, a monument has been erected by them to his memory in the Church of St. Leonard, Shoreditch.

His election into the Royal Society took place on the 2nd of June, 1853.

GEORGE BOOLE, by whose death mathematical science has suffered a great loss, was born at Lincoln on the 2nd of November, 1815. His father was a tradesman of very limited means, but held in high esteem by those who knew him. Having nothing to support his family but his daily toil, it was not to be expected that he could expend much on the education of his children; yet they were not neglected. Being himself a man of thoughtful and studious habits, possessed of an active and ingenious mind, and attached to the pursuit of science, particularly of mathematics, he sought to imbue his children with a love of learning, and employed his leisure hours in imparting to them the elements of education. His son George was sent first to the National School, and afterwards to a private Commercial School, conducted by the late Mr. Thomas Bainbridge, Lincoln. From his father he received his principal instruction in the rudiments of mathematics, and from him also he inherited a taste for the construction and adaptation of optical instruments. It was not, however, until a comparatively late period of his earlier studies that his special aptitude for mathematical investigations developed itself. His earlier ambition seems to have pointed to the attainment of proficiency in the ancient classical languages; but his father being unable to assist him in overcoming the first difficulties of this course of study, he was indebted to a neighbouring bookseller (Mr. William Brooke) for instruction in the elements of Latin grammar. To the study of Latin he soon added that of Greek, without any external assistance, and for some years he devoured every Greek and Latin author that came within his reach.

At the age of sixteen he became an assistant in a school at Doncaster; subsequently he occupied a similar post at Waddington, a village about four miles from Lincoln. In these situations, besides prosecuting his studies in the ancient classics, he cultivated an acquaintance with the best English authors, and began to read the German, French, and Italian languages, in all of which he ultimately attained singular proficiency.

Two of his latest mathematical essays were written, one in German, and the other in French. As he had at this time a great wish to take orders in the church, he applied himself for two years to the study of patristic literature by way of preparation for the regular theological course. But the circumstances of his parents and some other difficulties hindered the accomplishment of this design. In his twentieth year he decided on opening a school on his own account in his native city. Henceforward mathematics became his special study.

His earliest papers, written, as he himself incidentally mentions, toward the close of the year 1838, were prepared during his perusal of the *Mécanique Analytique*, in the form of "Notes on Lagrange." From these notes in the following year he made selections, and wrote out what appears to have been his first paper (though not the first published), titled "On certain Theorems in the Calculus of Variations," wherein he proposed various improvements on methods of investigation employed by the illustrious French analyst. About the same time his attention was attracted to the transformation of homogeneous functions by linear substitutions, a problem which occupies a very conspicuous place in the writings of Lagrange, and which had also employed the powers of Laplace, Besque, Jacobi, and other distinguished continental mathematicians. The manner in which Boole dealt with this important problem showed him once to be a man of most original and independent thought, and in the course of his investigations he was led to discoveries which may be regarded as the foundation of what has been called the Modern Higher Algebra. His first published paper relates to this subject; and although he afterwards greatly improved and extended his method of analysis, yet his original memoir, entitled "Researches on the Theory of Analytical Transformations, with a Special Application to the Reduction of the General Equation of the Second Order," is interesting as showing how the subject first struck his mind. This memoir he communicated in 1839 to the Cambridge Mathematical Journal. Other papers in rapid succession followed. The generous assistance of the editor, the late Mr. Duncan F. Gregory, in correcting the imperfections of style which naturally resulted from his want of proper early training, Boole remembered with pleasure and thankfulness to the end of his life. His rising reputation led his friends to wish that he should enter himself at Cambridge. This project also was abandoned, and he continued to work amidst the interruptions and anxieties incident to the occupation of a schoolmaster. While applying the doctrine of the separation of symbols to the solution of differential equations with variable coefficients, Mr. Boole was led to devise a *general method in analysis*. The work was too elaborate and weighty for the mathematical journal; and he therefore, by the advice of Mr. Gregory, communicated a paper on the subject to this Society. For this paper, which was printed in the Transactions for 1844, he received the Royal Medal.

In the course of these speculations, and others of a like nature which grew out of them, Mr. Boole was led to consider the possibility of constructing a calculus of deductive reasoning. The severe discipline of his efforts to extend the powers of the analysis had given him not only a complete mastery over its mechanical processes, but also, what was of far greater advantage, a profound insight into its logical principles. In tracing out those principles he discovered that they admitted of an application to other objects of thought than number and quantity; he found, in fact, that logical symbols in general conform to the same fundamental laws which govern the symbols of algebra in particular, while they are subject also to a certain special law. This discovery suggested a variety of inquiries which he seems at different periods to have pursued, but without any intention of publishing his views on the subject. In the spring of the year 1847, however, his attention was drawn to the question then moved between Sir W. Hamilton of Edinburgh and Professor De Morgan, and he "was induced by the interest which it inspired, to resume the almost forgotten thread of former inquiries." His views were embodied in a remarkable essay, entitled "The Mathematical Analysis of Logic," which in the autumn of the year was put on sale in Cambridge and London. Early in the following year (1848) he communicated to the Cambridge and Dublin Mathematical Journal a paper on the "Calculus of Logic," in which, after premising the notation and fundamental positions of his essay, he gave some further developments of his system. From this time forward he applied himself diligently to a course of study and reflection on psychological subjects, with a view to the production of a much more elaborate and exhaustive work than either of those above named. He felt that the inquiry was one of great importance, and that in labouring to perfect his theory he was rendering essential service to science. He meditated deeply on the nature and constitution of the human intellect. The most eminent authorities, both ancient and modern, were consulted; opinions differing widely from each other, and often wholly opposed to his own, were carefully considered; and whatever was likely to help him in the great work which he had undertaken, was eagerly sought. Mental science became his study; mathematics were his recreation. So he has been heard to say; and yet it is a remarkable fact, and one which serves to show the great power and genius of the man, that his most valuable and important mathematical works were produced after he had commenced his psychological investigations.

In 1849 he was appointed to the Mathematical Chair in the newly formed Queen's College at Cork; and when the Queen's Colleges of Belfast, Galway, and Cork were united so as to form the Queen's University of Ireland, he was chosen one of the public examiners for degrees. These offices he filled with the highest reputation. In 1852 the University of Dublin conferred upon him the honorary title of LL.D., in company with

the late Judge Hargreave, "in consideration of their eminent services in the advancement of mathematical science." Late in the year 1853 Dr. Boole brought to its close a labour on which he had bestowed a vast amount of profound and patient thought. His "Mathematical Analysis of Logic" was written hastily, and on this account he afterwards regretted its publication; but the work which he now gave to the world must be regarded as the most carefully matured of all his productions. It is entitled "An Investigation of the Laws of Thought, on which are founded the Mathematical Theories of Logic and Probabilities." The principle on which the investigation proceeds is essentially the same as that enunciated by the author in his earlier logical essays; but, as he himself remarks, "its methods are more general, and its range of applications far wider." This great work was published in 1854.

During the remaining ten years of his life he contributed to various scientific journals papers on Probabilities, on Partial Differential Equations, on the Comparison of Transcendents, and on other high mathematical subjects. He also produced two text-books, one on 'Differential Equations,' and one on 'Finite Differences'—works which display a vast amount of original research as well as an extensive acquaintance with the writings of others. These have become class-books at Cambridge.

In 1855 Dr. Boole was married to Miss Mary Everest, daughter of the Rev. T. R. Everest, Rector of Wickwar, Gloucestershire, and niece of Colonel Sir George Everest, F.R.S., lately deceased, as also of Dr. Ryall, the Vice-President and Professor of Greek in Queen's College, Cork. The union was one of great mutual happiness, and was blessed with a family of five daughters.

In 1857 Dr. Boole communicated to the Royal Society of Edinburgh a memoir "On the Application of the Theory of Probabilities to the Question of the Combination of Testimonies or Judgments." For this purpose there was awarded to him the Keith Medal, the highest honour in the shape of prize which that Society has at its disposal. In June of the same year he was elected a Fellow of this Society. At the Oxford Commemoration in 1859 he received the honorary degree of D.C.L.

Soon after the publication of his Treatise on Differential Equations, Professor Boole resolved that if a new edition of the work should be called for he would reconstruct it on a more extended scale. For several succeeding years his studies and researches were largely inspired and directed by this object, which, however, he did not live to accomplish. The treatise had been for some time out of print, and he was engaged in preparing a new and enlarged edition when he was suddenly struck by the hand of death.

He had walked from his residence at Ballintemple to the College in Cork, a distance of little more than two miles, in a drenching rain, and lectured in his wet clothes. The result was a feverish cold, which soon

fell upon his lungs and terminated fatally. He died on the 8th of December, 1864.

Dr. Boole was a man of great goodness of heart. By those who knew him intimately he was regarded with a feeling akin to reverence. "Apart from his intellectual superiority," says one of his colleagues, "there was shed around him an atmosphere of purity and moral elevation, which was felt by all who were admitted within its influence. And over all his gifts and graces there was thrown the charm of a true humility, and an apparent total unconsciousness of his own worth and wisdom."

Many illustrations might be given of the versatility of Boole's talent, his love of poetry and music, his fine appreciation of the beauties of external nature, his profound reverence for truth, especially religious truth, and many other qualities of his intellect and heart which have not been so much as touched upon; but the limits within which it is proper that this sketch should be contained forbid any elaborate estimate of his character.

Boole's mathematical researches have exercised a very considerable influence upon the study of the higher branches of the analysis, especially in this country. They have stimulated and directed the efforts of other investigators to an extent that is not perhaps generally known. Out of his theory of linear transformations has grown the more general theory of covariants (due to Professor Cayley), with all its important geometrical and other applications. By his invention of an algebra of non-commutative symbols, a great impulse has been given to the cultivation of the calculus of operations. His general method in analysis is the most powerful instrument which we possess for the integration of differential equations, whether total or partial. To Sir John Herschel is due the high praise of having first applied the method of the separation of symbols to the solution of linear differential equations with constant coefficients. But it was reserved for Duncan F. Gregory and Boole to set the logical principles of that method in a clear and satisfactory light; and to Boole alone belongs the honour of having extended the theory to the solution of equations with variable coefficients. His principal discoveries in this department will be found in his 'Differential Equations,' and the Supplementary volume (edited by Mr. Isaac Todhunter), works which though primarily intended for elementary instruction, may be read with advantage by the advanced mathematical student. Other original investigations will be found in the same volumes, and more especially in those parts which relate to Riccati's equation, to integrating factors, to singular solutions, to the inverse problems of geometry and optics, to partial differential equations, and to the projection of a surface on a plane.

The calculus of logic, upon the invention of which Boole's fame as a philosophical mathematician may be permitted to rest, is most fully developed in his 'Investigation of the Laws of Thought.' The design of this work is—to use the author's own words—"to investigate the fundamental

laws of those operations of the mind by which reasoning is performed ; to give expression to them in the symbolical language of a Calculus, and upon this foundation to establish the science of logic, and construct its method ; to make that method itself the basis of a general method for the application of the mathematical doctrine of Probabilities ; and, finally, to collect from the various elements of truth, brought to view in the course of these inquiries, some probable intimations concerning the nature and constitution of the human mind."

Boole has left behind him a considerable quantity of logical manuscripts ; these will perhaps be published either in a separate form or in a new edition of the 'Laws of Thought.' His works are his noblest monument, but his friends and admirers have raised other memorials. Of these we may mention in particular, a memorial window in the Cathedral of Lincoln, and another in the College Hall at Cork.

The following is a list of Professor Boole's papers printed in the Philosophical Transactions. "On a General Method in Analysis," 1844, pp. 225-282. "On the Comparison of Transcendents, with certain applications to the Theory of Definite Integrals," 1857, pp. 745-803. "On the Theory of Probabilities," 1862, pp. 225-252. "On Simultaneous Differential Equations of the First Order in which the Number of the Variables exceeds by more than one the Number of the Equations," 1862, pp. 437-444. "On the Differential Equations of Dynamics. A Sequel to a paper on Simultaneous Differential Equations," 1863, pp. 485-501. "On the Differential Equations which determine the form of the Roots of Algebraic Equations," 1864, pp. 733-755.

SAMUEL HUNTER CHRISTIE was born in London on the 22nd of March, 1784, and at a very early age showed the talent for mathematical pursuits which afterwards so highly distinguished him. He was entered at Trinity College, Cambridge, in 1801, and, in his third year, obtained a scholarship. In 1805 he took his degree of Bachelor of Arts as Second Wrangler, having a severe struggle with Turton (afterwards Bishop of Exeter) for the "Blue Riband" of the University, and being bracketed with him as Smith's-prizeman. In 1806 Mr. Christie was appointed Third Mathematical Master at the Royal Military Academy at Woolwich, and immediately devoted himself to the improvement of the mathematical studies at that College, and persevered in the work with much success, during his lengthened career of forty-eight years in the public service. In 1812 he established the system of competitive examinations, but was unable fully to carry out his views in this and in other respects until his advancement to the post of Professor of Mathematics in 1838. It is not too much to say that no two educational institutions could present a stronger contrast than the Royal Military Academy in 1806, and the same College in 1854 when Mr. Christie resigned the Professor's Chair ; and this