supported by palæoclimatic evidence ; and now that rather convincing palæomagnetic evidence has been discovered[15], they find equally decisive reasons why it could not be otherwise.

[1] Darwin, G. H., *Phil. Trans. Roy. Soc.*, Pt. 1, **167**, 271 (1877). Reprinted in "Scientific Papers", **3**, 1 (Cambridge, 1910).
[2] Gold, T., *Nature*, **175**, 526 (1955).
[3] Thomson, Sir W., and Tait, P. G., "Natural Philosophy", **1** (first edition), 702 (Oxford, 1867).
[4] Rep. Brit. Assoc. for the Adv. of Sci., 1–12 (1876).
[5] Barnard. J. G., *Smithsonian Contr. to Knowledge*, 240 (1871).
[6] Darwin, Charles, *Phil. Trans.*, **81** (1839).
[7] Darwin, Sir G., "Scientific Papers", **5**, xv (Cambridge, 1916).
[8] Darwin, Sir G., "Scientific Papers", **2**, 501 (Cambridge, 1908).
[9] Darwin, Sir G., "Scientific Papers", **3**, v (Cambridge, 1910).
[10] Thomson, Sir W., "Mathematical and Physical Papers", **3**. 333 (Cambridge, 1890).
[11] Lambert, W. D., *Bull. U.S. Nat. Res. Coun.*, No. 78, Chap. 16 (1931).
[12] Jeffreys, Sir H., "The Earth", 343 (Cambridge, 1952).
[13] Darwin, Sir G., "Scientific Papers", **5**, 37 (Cambridge, 1916).
[14] Barrell, J., *Science*, **40**, 333 (1914).
[15] Irving, E., thesis (Cambridge, 1954). Clegg, J. A., Almond, M., and Stubbs, P. H. S., *Phil. Mag.*, **45**, 583 (1954). Creer, K. M., thesis (Cambridge, 1955). Runcorn, S. K., "Adv. Phys.", **4**, 244 (1955).

BOOLE'S "THE LAWS OF THOUGHT"

By F. I. G. RAWLINS

THE Royal Irish Academy has done well to collect and issue a series of papers* commemorating the appearance of "The Laws of Thought" by George Boole in 1854. The occasion was a centenary celebration in Dublin, and here is a permanent record, bearing witness both to the unique character of the book itself, and in parallel, so to say, to the remarkable personality of its author. If ever a publication reflected the innermost being of its originator, this volume assuredly did. Its production, moreover, stands as a monument to the foresight of the electors to the chair of mathematics at Queen's College, Cork, who appointed a candidate without a university degree, and devoid of formal academic training. It is rather as if a similar choice had been made of Ramanujan many decades later, before he went to Trinity College, Cambridge, to carry all before him.

Most appropriately, Sir Geoffrey Taylor opens the series with a graphic account of his grandfather's life. And what a life it must have been ; serene, highly disciplined, creative at every stage, both in research and in the task of imparting knowledge. For even when Boole was school-mastering in Lincoln as little more than a youth he was experiencing the joy of discovery, as he read and mastered the works of the French mathematicians. Alongside all this, he taught himself several languages, as if to foreshadow the development of semantics as the century wore on.

Boole had a great appreciation of the place of tranquillity in the intellectual life. We read of him taking a "solitude à deux" with a friend to the Alkborough Hills near his peaceful Trent, and sitting down alone under a bush in the evening. From this excursion arose the precursor of his analytical studies which he later improved and expanded in "The Laws of Thought". At times his inclination seems to have been towards algebraic methods rather than in the direction of geometry, believing the former to be the more powerful instrument. But as we shall see later, this was no lopsided view. His grasp was so sure that, analyst as he sometimes was, history will credit him as a great architect in synthesis.

How exactly did this come about ? The answer is to be found in Boole's attitude to Nature. He believed profoundly that there was such a thing as unity *of* Nature, and unity *in* Nature. In these two concepts, which went far to mould the entire pattern of his life, he approximated to Leonardo da Vinci, with his deep veneration for natural law. The method of Boole is based upon this one-ness, and enmeshed in it are the seeds from which has flowered much of the propositional calculus as we now have it, and a great part of the powerful machinery of modern logistics. It must not be too readily deduced from this, however, that the meta-sciences of to-day spring directly from "The Laws of Thought" ; what has in fact happened is that out of traditional logic has appeared a means whereby it has become possible to raise such a majestic structure that the elements of Aristotelian thought still embedded in it comprise but a minute fraction of the whole. It is an example on the grand scale of the eternal verity that nothing can be quickened except it die. The sower of that particular harvest was George Boole.

We can now, with this in mind, attempt some appraisal of the method of this remarkable man, and we shall not get far without observing certain features in common with the outlook of Alfred North Whitehead. It is probably no accident that much the same logical pressure acted upon the mind of Boole as it did much later upon the authors of "Principia Mathematica". The essence of his method is to begin with things rather than words ; with objects before concepts. Then follows the paramount need to train the mind by rigorous exercise, including the working out of numerous examples. One may compare this with Whitehead's belief in the use of the simplest possible apparatus, to squeeze the last drop of juice out of any problem amenable to experiment. Just as Leonardo da Vinci took infinite pains (somewhat against the grain) to study the works of Archimedes, so we find Boole ever ready to relate his abstractions to things as we find them. His insistence upon the acquisition of a beautiful and legible handwriting gives us a clue to the importance which he attached to means as well as ends. He was human enough to seek relief from pure speculation by resorting sometimes to "mechanical employments", while conversation he regarded as an entertainment, not as an occasion for strife.

Strong traditionalist as he was—as we have already seen—Boole's concept of the construction of a physical science has a present-day familiar look. In "The Laws of Thought" he finds four stages : namely, observation, presumption (that a law exists), experimental tests, and the investigation of causes. In addition, his emphasis upon increasing probability towards the limit of certainty as confirmatory data increased shows how sure an insight he had of a

* Proceedings of the Royal Irish Academy. Vol. 57, Section A, No. 6 : Celebration of the Centenary of "The Laws of Thought" by George Boole. Pp. 63–130. (Dublin : Hodges, Figgis and Co., Ltd., 1955.) 6*s*.

methodology well ahead of his time. This is noteworthy when one recollects that Boole was working at a period when laboratory techniques were very limited and—supposedly—his own contacts with them of the most slender kind.

In passing from here to some evaluation of Boole's place in logic, the elementary fact of history—that the subject had been static "at the same level of very elementary deduction" for some two thousand years—throws into relief the achievement of infusing new life in the form of a conscious mathematical logic into something which had eluded Leibniz and Lambert many years before. All this was propounded in the "Mathematical Analysis of Logic" (1847), and elaborated in "The Laws of Thought". In essence, Boole set about calculating as an algebraist would, afterwards eliminating such terms as were incapable of a logical interpretation. According to him, however, the equality $xx = x$ is unique. In ordinary algebra this is only true for $x = 1$ and $x = 0$, whereas in logic it holds for all values of x. From this he goes on to assume that the laws of his algebra only exceed those of ordinary algebra in this one particular. A number of criticisms have been made of Boole's system both in regard to mathematical rigour, and touching the æsthetic point that in some degree it lacked elegance. No doubt, as one commentator observes, there were some tares among the wheat, and they grew together until the harvest. Time has exterminated the chaff.

A trio of papers in the collection under notice brings the story of Boole's genius up to date by a discussion of the relation of his methods to contemporary many-valued logics, his concept of a function, and the influence of institutionalism upon the classical algebra of logic. Finally, comes a contribution dealing with an engineering application of Boolean algebra, which turns out to be an extremely powerful calculus for the determination of electrical circuits comprising two-state switches, that is, those that can be only 'on' or 'off'. In the case of complex problems in telephony, it can make possible major advances in communication theory, by simplifying equations otherwise almost unmanageable in practice.

In brief, the life and work of George Boole as reflected in "The Laws of Thought" are the perfect illustration of the truth of Whitehead's dictum: "You may not divide the seamless coat of learning".

THE COLE MUSEUM OF ZOOLOGY

UNIVERSITY OF READING

IT is fifty years since the appointment of Prof. F. J. Cole to the Department of Zoology in University College, Reading (now the University of Reading). One of the factors that contributed to Reading's rise to the status of a university was the fact that several men and women of high quality identified their careers with her, and Prof. Cole was one of them. Soon after his arrival he started to build up a museum of zoology, and when he retired in 1939 he had the satisfaction of seeing his Department endowed with one of the finest teaching museums in Great Britain. An appreciative Council decreed that it should remain as a permanent memorial to him with the name of 'The Cole Museum of Zoology'.

Small though the Department was, it was from the beginning the special duty of one of the members of the staff to care for the growth and maintenance of the Museum. From 1912 until 1919 this was Miss (now Dr.) Nellie B. Eales, and from 1921 to the present time Mr. W. E. Stoneman has held the curatorship.

The exhibits now number more than three thousand, and each is described in the manuscript catalogue, where references to original publications are found and drawings help to interpret intricate parts. This is the source-book for the Museum's history, and it is appropriate to celebrate its jubilee by recalling some of the highlights.

Prof. Cole appealed to zoological friends all over the world, asking for particular animals in accordance with a careful plan. Prof. Ijima of the University of Tokyo, a world authority on the Porifera, collected and prepared in his own laboratory the magnificent series of Hexactinellid sponges. He, moreover, went to sea six times before he succeeded in dredging from the depths of the ocean the fine sea-lily (*Metacrinus*) which now adorns the Echinoderm case. Skeletons of a record python and an orang were contributed by Dr. Hanitsch, formerly director of the Raffles Museum, Singapore. Mr. Alfred Palmer, by a generous donation, made possible the purchase of a fine gorilla skeleton to complete the Huxleyan series —gibbon, orang, chimpanzee, gorilla, man. Captain C. R. S. Pitman, when game-ranger of Uganda, sent such animals as the tree pangolin and the lung-fish, *Protopterus*. The Australian Government presented specimens of the echidna and the platypus, from which dissections, skeletons and stuffed skins were prepared. Dr. Johannes Schmidt provided a set of stages of the *Leptocephalus* larva (eel) up to its metamorphosis. An officer of an Antarctic whaling ship prepared a group of specimens to illustrate the auditory organ of the whale, and a beautiful and perfect exhibit is the result. From the *Discovery* collections also many gifts were received. Old students going abroad were briefed to obtain specimens, and to them the Museum owes its Java pangolin, West African manatee, bats and monkeys, Central African hyrax, giant millipedes and scorpions and Mauritian lemurs and tenrecs.

The fullest use was made of all this valuable material. A single *Cryptobranchus* from Japan yielded a complete skeleton and preparations of the heart, arterial arches, gut, renal and reproductive organs, as well as a stuffed skin.

Dissections form a major part of the collection, and they include numerous injections of blood vessels, lymphatics and air-sacs. A former student, Dr. D. M. Tompsett, prosector at the Museum of the Royal College of Surgeons, prepared an exquisite Marco resin cast of the pulmonary vessels and bronchi of a sheep, and another of the cavities of the human brain, both of which were presented by the College.

Transparencies, in which the bones and cartilages are stained to show the skeletal parts *in situ*, have been made by Mr. Stoneman. There are wax models