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CHANGING CONCEPTIONS OF ATOMISM: DEMOCRITUS TO 1957

By MR. L. L. WHYTE

ABSTRACT of Paper read on 25 *March*, 1958

One way of discovering hidden and possibly redundant assumptions in a contemporary theory is to contrast it with some other theory. Thus a historical survey of the different expressions of the atomic hypothesis from the ancient Greeks onwards may throw light on the problems of current particle theory. Leaving on one side Mach's view that atoms are "mental artifices" capable of possessing any desired properties, eight distinct conceptions of "atoms" were discussed in historical sequence: 1. The Democritan-Newtonian hard finite particle; 2. the Boscovich point centre of action; 3. the Kelvin vortex ring and other spinning units; 4. the "negative" atom or hole of Osborne Reynolds and Dirac; 5. the de Broglie wave-particle in three dimensions; 6. the quantum-mechanical probability fields in higher spaces; 7. the unstable "elementary" particles discovered since the 1930s; and 8. various recent neo-quantum-mechanical conceptions, such as Bohm's speculative ideas, and neo-relativistic entities, exemplified by Wheeler's "geons". This survey led to certain conclusions, retrospective and prospective. One intention of the paper was to illustrate a type of research activity in which fresh methods of approach to unsolved problems might be suggested by a historical study of the changing methodology of exact science.

SCIENTIFIC LITERATURE AND THE CLASSIFICATION OF THE SCIENCES

By DR. H. D. ANTHONY

ABSTRACT of Paper read on 2 *June*, 1958

The purpose of the paper was to trace the way in which the various branches of science have come into being. As knowledge and experience increased, it was a logical procedure to provide appropriate divisions within which newly-

discovered facts could be arranged. Scientific literature developed in such a framework, and ultimately what had been regarded as major sciences were sub-divided into several sections.

Three main landmarks may be seen in this process. The first, Aristotle's classification into physics, mathematics and metaphysics. The second, classification into several branches of science, as a consequence of the general acceptance of the experimental method. The third, the recognition of the inter-relation of the sciences, which resulted from more detailed observation and improvement in experimental technique. Such classifications as bio-chemistry were convenient and inevitable for both teaching and research.

Perhaps the second half of the twentieth century may witness a fourth phase—the widening of the contacts of science in the study of science and history, with the history of science as a connecting theme. Such a development would have a far-reaching effect on education, and would lead to the recognition of science as an important cultural contribution to life. (*A more detailed Abstract was given in Bulletin No.* 19).

THE ROLE OF EQUALITY AND INEQUALITY IN THE HISTORY OF MATHEMATICS

By DR. R. C. H. TANNER

ABSTRACT of Paper read on 20 *October*, 1958

Inequality signs ($<$ and $>$) date from Harriot's *ARTIS ANALYTICÆ PRAXIS*, given out by Walter Warner in 1631 ; before this *greater than* and *less than* were expressed verbally. A stated small amount *more* or *less* was indicated by the signs + and − in 1489 by the German merchant Widman ; the only earlier algebraic signs are the numerals.

" Mathematics begins with numeration ", true only in the *history of mathematical notation*, becomes " Mathematics begins with inequality " in the *history of mathematical ideas ;* for the most primitive number-system implies a sense of *equal* and *unequal*, of *more* and *less*, notions enshrined in the most rudimentary language—in the *comparatives*. *More* and *less* would be easy to assess in practice, *equality* harder. *Surplus* and *defect* had to be ruled out : *equal* means *neither more nor less*.

The *history of mathematical inequality* and the *history of the inequality SIGNS* are mutually illuminating. Finished mathematics, for show, has always stressed *equality* though *inequality* is the touchstone behind the scenes. But mathematics is no more a set of *results* than a set of *signs*, and like any other discipline is characterised by its *workshop methods*. Inequality comes into its own in *proofs* and *applications* of equalities.

In this setting the history of the signs is of unusual interest for the historian and humanist. Printing began in 1450 and put an end gradually to the extensive abbreviation, precursor of our symbolic writing of mathematics. The only earlier signs much in use, geometrical ones, did not survive long in print ;

algebra *took over* from there a symbolism soon to become an integral characteristic, a chapter in logic, not, as formerly, mere shorthand.

The equality sign = was adopted by Robert Recorde in 1557 and first printed in 1618. In geometry it had long meant " are parallel ". Harriot adapted this idea, making the upper line diverge from the lower towards the value indicated as the larger ∠ and ⦣. The left-hand pointing sign meant " angle " in geometry. As the place of geometry declined relatively to algebra and its derivative, the calculus, whose very foundations are rooted in inequalities, this clash became unimportant and the resistance to Harriot's suggestion gradually faded out. Other circumstances too of his invention explain both this resistance and the intrinsic excellence by which his signs won through, so completely that mathematics would be crippled without them. Harriot was no mathematical genius. He was British, with a higher standard of accurate exposition and correct inference than he found easy to sustain and—not unlike Darwin—unskilled in self-vindication.

THE EVOLUTION OF OUR NUMERALS AND SYSTEM OF NUMERATION

By DR. G. J. WHITROW

ABSTRACT of Paper read on 24 *November*, 1958

Three systems of numeration involving the idea of place value and the use of a symbol for zero have been developed in the past : the Maya, the Seleucid-Babylonian and the Hindu, but only the latter two could have influenced the modern system.

The late Babylonians improved the Sumerian-Akkadian sexagesimal system by introducing a medial zero not later than 300 B.C. Ptolemy (*circa* 150 A.D.) employed the sexagesimal system for fractions. He used a symbol for zero at the end of a number as well as medially, but the oldest manuscript copies of his work which survive are Byzantine. It is very unlikely that he used omicron to denote zero as it already had the significance of 70 in the Greek system. Indeed, other symbols for zero (as a blank) are found in Greek papyri.

The forms of our present numerals can be traced back to the Brahmi numbers of ancient India (second and third centuries B.C.). Sanskrit with its large number of numeration words for powers of 10 readily lent itself to the development of the place-value principle. One of the most striking arguments (the alleged sudden reversal of symbolic order) on which Hans Freudenthal bases his theory that the Hindus perfected their system of numeration only as the result of coming into contact with Hellenistic astronomy involving the sexagesimal system including zero can be shown to be baseless. On the other hand, since the use of zero in calculation (as distinct from recording a mere blank) is the most remarkable feature of the modern system, Brahmagupta's formulation (*circa* 625 A.D.) of an operational definition of zero as a number is significant, although not conclusive, evidence for the theory that our system is *mainly* Hindu in origin, despite the probable influence of the sexagesimal system.

THE FOUNDATION OF THE ASHMOLEAN MUSEUM

By DR. C. H. JOSTEN

SYNOPSIS of Paper read on 21 *February*, 1959, *at the Ashmolean Museum, Oxford.*

The circumstances leading to the foundation of the Ashmolean Museum have been misrepresented by a number of nineteenth and twentieth century writers. A brief sketch of Elias Ashmole's personality. The Tradescants and their collection. Between 1652 and 1656, Ashmole and Dr. Thomas Wharton prepare a catalogue of the Tradescant collection. In 1659, the Tradescant collection is given to Ashmole. Ashmole's lawsuit with the widow of John Tradescant the younger, 1662–1664. About 1674, Ashmole conceives the idea of founding a public museum. His further disputes with Mrs. Tradescant. Ashmole's first negotiations with the University of Oxford concerning his gift. Izaak Walton's account of zoological specimens in the Tradescant collection. Mrs. Tradescant's confession, 1676. Plans for the building of the Ashmolean Museum and for the establishment of a lecture in natural philosophy are discussed in 1677. Dr. Robert Plot to become the first Keeper of the Museum. Mrs Tradescant's death, 1678. Ashmole's lawsuit with her executrices. The building of the Ashmolean Museum begun in 1679. Possible influence of Sir Christopher Wren on the design. Ashmole's first draft of rules for the administration of the Museum, 1682. The establishment of an Ashmolean Professorship in Natural History and Chemistry is prevented by ecclesiastical influence. The opening of the Ashmolean Museum in 1683. The University appoints Dr. Robert Plot Professor of Chemistry. His lectures and the foundation of the Philosophical Society of Oxford. Benefactions to the early Museum. Ashmole's statutes for the administration of the Museum, 1686. The endowment of the Museum proves insufficient. Ashmole's bequests to his Museum. Plot's views on fossils; those of his successor, Edward Lhuyd. Ashmole's dissatisfaction with Plot; his prejudice against Lhuyd. The decline of the Ashmolean Museum in the eighteenth century. Its disruption as a scientific institution in the nineteenth. The foundation of the Museum of the History of Science in the Old Ashmolean Museum. *Dr. Josten kindly invited Members to view the Ashmolean Collection after his lecture.*

THE BACKGROUND AND EVOLUTION OF THE METHOD OF LEAST SQUARES

By DR. CHURCHILL EISENHART
National Bureau of Standards, Washington, D.C., U.S.A.

ABSTRACT of Paper read on 4 *May*, 1959.

The Method of Least Squares evolved in the early 19th century in response to the need for a " best " procedure for the adjustment of observations in astronomy and geodesy ; and as the culmination of three distinctly different lines of development that start from different premises, have different aims, and place different interpretations on the end results of its applications. All three

evolved from the *Principle of the Arithmetic Mean*, which may be of sixteenth-century origin. The first stemmed from the principle of zero sum of residuals, to which Boscovich (1757) added the requirement of equal sums of positive and negative residuals, and culminated in Legendre's (1805) recommendation of the technique of *MINIMUM SUM OF SQUARED RESIDUALS* on purely functional grounds of generality, ease of application, and uniqueness of solutions. No probability considerations were involved. The second began with Simpson's (1755) introduction of *probability distributions of errors* (for the purpose of justifying the Principle of the Arithmetic Mean), and culminated in Gauss's (1809) "derivation" of the technique of Minimum Sum of Square Residuals, from the Principle of the Arithmetic Mean, with the aid of Bayes's (1763) *method of inverse probability*. The third stemmed from Simpson's work just cited and from Laplace's (1774) application of the concept of a *loss function* to the problem of obtaining the "best mean", and culminated in Gauss's (1821) demonstration of the great generality and simplicity of the Principle of MINIMUM MEAN SQUARED ERROR OF ESTIMATE and its equivalence with the technique of Minimum Sum of Squared Residuals when the "answer" is a linear function of the observations. This duality appears to be a unique property of "Least Squares".

At the Annual General Meeting, held on 22nd June, 1959, The President, Dr. E. Ashworth Underwood, showed two films dealing with the history of science and technology:

(*a*) STONE AGE TOOLS

This film, made in 1947 by the Wellcome Film Unit, demonstrates the methods developed by M. Léon Coutier of Paris in the making of artifacts such as were used by prehistoric man in the stages of his Stone Age cultural development.

It is well known that different techniques were employed in the making of different implements and in different industries. Archaeologists were long divided regarding the actual technique, but there have been few attempts to imitate the methods of manufacture. M. Coutier, who was formerly President of the Société Préhistorique Française, had a monumental mason's business, and he experimented for many years in an effort to recapture some of the prehistoric techniques. How admirably he succeeded is shown by this film.

M. Coutier was induced by his friend Mr. A. D. Lacaille, M.A., F.S.A., Archaeologist to the Wellcome Historical Medical Museum, to allow this demonstration to be made. Mr. Lacaille was present at the meeting and showed some of the hand-axes, gravers, and arrow-heads made by M. Coutier, together with comparable prehistoric examples, and also the actual tools used by M. Coutier in his work.

(b) WILLIAM HARVEY AND THE CIRCULATION OF THE BLOOD

(*By permission of the Royal College of Physicians*)

William Harvey (1578–1657) was elected a Fellow of the Royal College of Physicians in 1607, Physician to St. Bartholomew's Hospital in 1609, and Lumleian Lecturer to the College in 1615. The notes which he made for his

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first course of lectures are still extant, and they show that he had then appreciated the fact that the blood circulates in the vessels of the body. During the next thirteen years he experimented unceasingly, and in 1628 he published his first statement of these experiments. This work, *Exercitatio anatomica de motu cordis et sanguinis in animalibus*, transformed the whole future of physiology and scientific medicine.

On the occasion of the third centenary of that event in 1928 a film of Harvey's experiments was made by Sir Henry Dale and Sir Thomas Lewis for the Royal College of Physicians. It was decided to re-make this film to commemorate the tercentenary of Harvey's death in 1957. This new version is in colour and has a sound-track. It was made for the Royal College of Physicians by the Wellcome Film Unit with a grant from the Wellcome Trustees. It was again made under the supervision of Sir Henry Dale, who is shown speaking the introduction. The experimental work was carried out at University College, London, by Professor Michael de Burgh Daly, now of St. Bartholomew's Hospital, and Dr. Leonard G. Goodwin, of the Wellcome Laboratories of Tropical Medicine. The resulting film gives an insight into Harvey's work and methods which could never be obtained solely from the printed word.

THE HISTORY OF THE CONCEPT OF MASS

By DR. G. BURNISTON BROWN

ABSTRACT of Paper read on 19 *October*, 1959

One of the most astonishing features of the history of physics is the confusion which surrounds the definition of the key term in dynamics—*mass*, a confusion which has existed almost from the day that Newton defined it. Originally defined as a *measure*, i.e. a number, it became something which a body had, which could be measured. Mach considered the definition " unfortunate ", Einstein " illusory ", and Somerfeld called it " a mock definition ". Yet without it Newton could not have laid the foundations of dynamics, succeeding where Galileo failed. A careful examination of the problem shows, with very little doubt, that when Newton used the word density he meant what we now call *relative density*. His definition of mass is then unexceptionable. What is unfortunate is that he allowed himself to speak of mass with the common meaning as well as with the special meaning he had given it. This perhaps accounts for the errors of the interpreters and popularisers of the Principia. Recently the terms *gravitational* and *inertial* mass have been coming into greater use, but the confusion has increased rather than diminished. The speaker's theory of inertia, which is in quantitative agreement with experiment, helps to lessen the confusion, both old and new.

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TRENDS IN NINETEENTH-CENTURY BIOLOGY

By DR. W. E. SWINTON

ABSTRACT of Paper read on 7 *December*, 1959

Biologically the nineteenth-century stage was CHARLES DARWIN'S. But there were important acts before his and there were consequences that were not entirely of his making.

It was essentially a century of three stages. New fields of discovery, new facts, new theories. A time in which the main progress was in three countries: France, Germany and England. In France the works of Giraud Soulavie, Geoffroi St Hilaire, Lamarck and Cuvier led to controversies that interested the world, not least the Germans, and stimulated Goethe. Goethe and Haeckel played their parts, though not always very clearly, in the new developments. In England, William Smith, Charles Lyell, Darwin, Herbert Spencer and Huxley used the new knowledge to the full and started the dawn of modern biology.

THIRTY CENTURIES OF ASSAYING

By MR. FRANK GREENAWAY

ABSTRACT of Paper read on 20 *January*, 1960

Assaying has been practised since antiquity, the process of cupellation having a longer continuous history than any other quantitative chemical process still surviving. The traditions of fire-assay were transmitted to medieval Europe, where it was constantly familiar to court officials, as is seen in such works as the *Dialogus de Scaccario* (*circa* 1180) and the *De Moneta* of Nicolas Oresme. One French edict of 1343 refers to the testing of lead for silver content to obviate false results, and to the care of balances.

The great metallurgical books of the sixteenth century (Probierbüchlein, Biringuccio, Agricola, Ercker, etc.), based on this tradition, show that throughout Europe methods were used with sufficient understanding for them to be applied even to the control of stages of a complex smelting process (liquation).

The wide acceptance of this tradition in the seventeenth century is seen in works of general economic interest (W. B.'s *New Touchstone* and Boizard's *Traite des Monnoies*).

In the eighteenth century critical studies of assaying contributed to the chemical revolution through such work as that of Tillet, examining sources of error in cupellation. Bergman's work on precipitation reactions contained important comment on the limitations of dry methods and set analytical chemistry on a path which led to, among other things, Gay-Lussac's argentometry of 1832. In this, for the first time since antiquity, an alternative to fire-assay was available for the estimation of silver. The fire-assay of gold retains its value to the present day.

FOUNDATIONS OF CURRENT ELECTRICITY AND ELECTRO-CHEMISTRY

By Dr. W. Cameron Walker

ABSTRACT of Paper read on 29 *February*, 1960

It is a common misconception that Volta's discovery of the electric current and his invention of the pile were based almost entirely upon the unexpected outcome of Galvani's work on irritability. That the words *Galvanism, galvanic, galvanised* and *galvanometer* came to be associated with voltaic electricity is evidence of that misconception. But to regard Galvani's discovery as the one source of Volta's inspiration is to ignore or greatly to underestimate other contributions to electrical knowledge, including those by Volta himself, which were made in the second half of the eighteenth century. Priestley, Canton, Cavallo, Walsh, Hunter, Cavendish, Bennett and Nicholson—each played some part in preparing the way for Volta's crowning achievement.

Volta, already the most skilful electrician of his time, eagerly entered the field of investigation begun by Galvani. In a series of letters written between 1792 and 1796, chiefly to Cavallo in England and to Gren of Halle, it is possible to trace the evolution of his ideas from a wholehearted acceptance of the animal electricity of Galvani to its complete rejection in favour of his own contact theory.

In the meantime, Fabbroni of Florence had noted the signs of chemical action which accompanied the contact of metals, Cavendish had synthesized water (1781) and the " electrization " of water had been effected by van Troostwyk and Deiman (1789) and by Pearson (1797). With the arrival in London of Volta's memoir of 1800 giving a full description of the pile, the stage was set for a new advance, beginning with the decomposition of water by Nicholson and Carlisle and followed almost at once by other phenomena noted by Cruikshank, Henry and Wollaston which were to be significant pointers to the further development of electro-chemistry by Davy, Berzelius and Faraday.

FARADAY AND THE ATOMIC THEORY

By Dr. L. Pearce Williams
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ABSTRACT of Paper read on 2 *May*, 1960

Michael Faraday is rightly regarded as one of the greatest experimentalists in the history of science. His very skill as a discoverer in the laboratory, however, has served to obscure the brilliance and daring of his theoretical insights.

It is well known that Faraday rejected the conventional atomism of the day and much of the legend of him as a strict empiricist derives from this rejection.

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Faraday was an atomist, a follower of Boscovich who used the concept of point-centres of force to unify his ideas on the problems of electrical conduction, electrostatic induction and electrochemical decomposition.

The speaker discussed the reason for Faraday's rejection of conventional theories of atomism, traced out the particular tradition from which Faraday derived his knowledge of point atoms, and showed how he applied this concept in his *Experimental Researches.*