decisive in the future depends much upon the direction in which the Church of England itself moves.

Father Hughes' work as a whole and in particular his vindication, in its context, of the English martyrs is specially opportune and welcome at a time when it is beginning to be realized that, as a preliminary to fruitful work for unity, the Reformation period needs intensive re-study and re-assessment by Catholics and non-Catholics in common. The English martyrs died for the Mass and the primacy of the Holy See, and we honour them because their blood-shedding kept alive in their native country that faith in the divinely constituted unity of the Catholic Church which is our inheritance, and apart from which no true Christian unity can be realized.

SCIENCE AND THE MAP OF KNOWLEDGE

E. F. CALDIN

THERE are many unresolved questions about the relations of the natural sciences to Aristotelean-Thomist philosophy, and the accurate placing of science on the map of intellectual activities is one of the most important objectives of our time. The prestige of science is still so high that the relative neglect of it by Thomists is unfortunate, and a positive approach is of great value. The American Dominicans have therefore done wisely as well as boldly in setting up a permanent institution where scientists and philosophers can meet and collaborate, with a permanent staff most of whom have been trained in one of the natural sciences as well as in the Thomist tradition. This institution is called the Albertus Magnus Lyceum for Natural Science and is situated in a suburb of Chicago. Its leaders hope that, by bringing men engaged in specialized research into contact with a homogeneous intellectual tradition, they will be able to help scientists towards a synthesis that they feel to be necessary for the health of science itself as well as for modern culture generally. Clearly this venture could be of the greatest importance.

The present volume[1] is a report of an ambitious five-week

1 *Science in Synthesis*. By W. H. Kane, O.P., J. D. Corcoran, O.P., B. M. Ashley, O.P., and R. J. Nogar, O.P. (Dominican College of St Thomas Aquinas, River Forest, Ill.; $3.50.)

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meeting held in 1952, at which a varied group of experts in philosophy, logic and the natural sciences considered the relations between modern science and the Aristotelean tradition. Physics, chemistry, biology and psychology were allotted a week each, and the final week was devoted to an attempt at synthesis. The method adopted was dialectical discussion of scientific classics such as Galileo's *Two New Sciences*, Harvey's *The Motion of the Heart and the Blood* and Freud's *The Interpretation of Dreams*, varied by lectures on set topics. Very wisely, the discussion was concentrated on the methods of the sciences, the kind of questions to be asked, and the kind of explanations to be reached, rather than on the detailed conclusions.

Biology is perhaps the science most convincingly treated in this work. The representative classic chosen for study is Harvey's *The Motion of the Heart and the Blood* (1628), in which was demonstrated the circulation of the blood. In a very interesting section, it is argued that the methodology used by Harvey was derived not from Bacon, nor from Galileo, but from Aristotle; that Harvey was seeking a true definition of the heart in terms of the four Aristotelean causes—its function, materials, structure and activity—and that this aim was realized in a definition of the heart as an organ constructed like a pump in order to circulate the blood by contracting. This investigation being taken as a model, it is suggested that biology should study living things by asking questions corresponding to the four causes. The organizing principle would then be the definition of life, in terms of self-movement. Attempts to organize the subject by the theory of evolution are criticized on the ground that one should start not with speculative theories but with broad obvious facts, such as the behaviour of organisms in tending to preserve their life and propagate their kind. A sketch of the way in which the biological disciplines might then be grouped is presented. Various aspects of the Aristotelean view of nature and of methodology are well brought out, and the treatment displays a thorough acquaintance with the modern literature as well as the ancient. It seems doubtful, however, whether justice is done to the aspects of modern biological science in which its methods most resemble those of physics and chemistry, such as genetics, or to those in which it makes most use of the conclusions of physics and chemistry.

The application of Aristotelean principles to the sciences of inanimate nature is notoriously difficult, and the treatments of physics and chemistry in this book reflect this difficulty. The initial debate on the method of modern physics, starting from Galileo's procedure, is indeed most interesting and well reported. It brings out the importance of mathematics and hypothesis in modern physics, and shows that the questions now asked by physicists differ from those asked by Aristoteleans, who seek to define the nature and other causes of each primary natural unit. The attempts at an Aristotelean critique and synthesis, however, are much less successful. The mathematizing procedure characteristic of modern physics and chemistry is alleged to be unsatisfactory, and it is claimed that these sciences are inadequate because they seek only material and efficient causes, omitting formal and final causes. Although the authors admit that the inanimate universe is not perhaps very intelligible to us, they seem to claim that we have enough insight into it not only to decide what are natural units but also to apprehend their natures with enough clarity to satisfy the Aristotelean ideal of science, in which through our knowledge of the nature of a thing we can state its essential properties. This is a large claim. The *status* of the atomic and molecular models, in terms of which the chemist works, is not examined. The problem of induction is brushed aside as due to nominalism.

The authors have many interesting things to say about Aristotle's methodology and view of nature, but their proposals for correcting the present directions of physics and chemistry on Aristotelean principles are woefully unconvincing. It seems difficult for enthusiastic Aristoteleans to realise that physical scientists do not seek primarily explanations in terms of material, formal, efficient and final causes; they seek to *correlate the phenomena*, first by empirical laws and then by theoretical constructions. An event is 'explained' if it can be shown to be an instance of a law, as for example lightning provides an instance of the laws of electricity. A law is 'explained' if it can be deduced from a theory, which may be embodied in a model; thus the spectrum emitted by all specimens of hydrogen gas is explained because it can be deduced from a model or mental picture of the gas as made up of isolated molecules each consisting of two protons and two electrons interacting electrically. It cannot be claimed that such a model corresponds exactly with reality; for one thing, an

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atom has to be pictured as particle for some purposes and as a wave for others. It can be argued that such models are *analogues* of the real; but we do not know how close or how distant that analogy may be. It may be said that we have here some approach to a knowledge of the nature of hydrogen (its formal cause) and of its material causes, namely protons and electrons; but that is not the approach by which the relevant discoveries were made. For the scientist, *quâ* scientist, the model gives a good explanation because it correlates the phenomena; from it we can deduce the spectrum, the specific heat, the thermal conductivity, and so on, and the deductions agree with experiment. Aristotelean interpretations may be fitted on to the model after it has been discovered; it may be susceptible of teleological explanations; but that is not the primary objective of the scientist, nor does it show the way to make discoveries in science. The physical scientist's first aim is to describe and correlate the phenomena, and for this all he needs is a partial knowledge of the formal cause. An enquiry directed primarily towards the proximate, efficient and final causes of the behaviour of inanimate nature seems to him of dubious interest and unlikely to have much success. This does not mean that he is necessarily unaware that such enquiries are of great importance in other fields. He may and should admit the need of an Aristotelean analysis of human acts, and of the all-important enquiry into the First Cause of the existence of the universe. It is in the detailed understanding of inanimate nature that he is sceptical of such an approach.

The reason why physical scientists do not conduct their investigations with the four types of cause in mind is not that they are nominalistic, nor that they are obsessed with analysis and mathematics, nor that they are uninterested in qualities. It is that experience has shown that a detailed account of the order of the natural inanimate world can be successfully reached if we start by trying to describe and correlate the phenomena, but not if we start by asking for their causes. The inanimate world is simply too remote from ourselves for a direct enquiry into causes to be fruitful.[2] Explanations of the Aristotelean kinds can readily be given for rational human actions; thus for some considered action of my own I can state the agent, the end, the circumstances,

2 The difficulty is given welcome stress by H. van Laer in his *Philosophico-Scientific Problème* (Pittsburgh, Duquesne University Press, 1953).

and (thanks to my intimate knowledge of myself) the nature of the agent; these are respectively the efficient, final, material and formal causes of the action. Explanations of these types can also be given for some of the characteristics of living organisms; we have noted that the action of the heart can be analysed in this way. Our knowledge of beings other than ourselves is indeed less direct than our self-knowledge; according to St Thomas, the only nature of which we can give an adequate definition is our human nature, that of a rational animal; but this knowledge of ourselves, who are organisms, gives us some insight into the nature of other organisms also. When we come to the inanimate world, however, we find it is so different from ourselves that its nature is opaque to our understanding. We cannot directly identify the natural units, nor their natures. What we can do is to describe exactly the phenomena of the inanimate world and seek correlations between them. Because correlation is most easily achieved and expressed by mathematical means, we choose where possible phenomena that can be expressed in or reduced to quantitative terms; this is the reason for the rapprochement of mathematics, physics and chemistry. When our authors call for re-orientations of physics and chemistry on lines derived from Aristotle's *Physics*, telling us that 'the fundamental problem of physics is that of changes in *place*, and in Chemistry that of changes in *quality*', they seem to forget these lessons of the history of science. Modern physics and chemistry are seeking explanations of the inanimate world of the kind that is *prima facie* possible. If anyone wishes to use these scientific explanations as a basis on which to speculate about Aristotelean causes, well and good; but the scientific explanations will not be reached if the investigator has those causes primarily in mind. The explanations to which the procedures of physical science naturally lead are explanations by correlations, not by the four causes; and these procedures have been adopted because they have been found by experience to be the ones suited to the study of inanimate things.

The special difficulty of finding causal explanations for inanimate nature did not deter Aristotle from the attempt; living at the dawn of the scientific investigation of nature, it was natural for him to assume that explanations of the types that could successfully be given for human actions and for the behaviour of organisms could also be given for the inorganic world, though

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with greater difficulty. But because he had not appreciated how great would be the difficulty, he had developed no special methods for elucidating the regularities in the physical world, for finding and refining empirical laws or correlations. Nor were these methods developed in the Islamic tradition which inherited, developed and ultimately passed on to medieval Europe the Aristotelean scientific knowledge. They were initiated in the thirteenth century by Robert Grosseteste and the Franciscan school at Oxford, who, as Dr Crombie has recently shown,[3] realized the roles of diversified observation, of experiment, of hypothesis and of mathematics, and thus initiated the methodology of empirical inductive science. (They still regarded their methods as leading to a knowledge of causes.) Despite their great methodological advances, however, little progress was made in achieving scientific results. Meanwhile the influence of the philosophers who are roughly classified as 'nominalist' was increasing, and these men—Occam, for example—began to drop the Aristotelean causes as explanations and to substitute the notion of correlation; they began to define 'cause' in terms of invariable succession of types of events. The disastrous effects of this in the sciences of human affairs are apparent; but the sciences of inanimate nature are another matter. It was in this 'nominalist' tradition that the methodology of inductive discovery was developed, during the fifteenth and sixteenth centuries, in the universities of Northern Italy, especially at Padua, where the professors of the great medical school (at which Harvey later studied) collaborated with the logicians.[4] This was the methodology which Galileo inherited and proceeded to use with unprecedented mastery. He explicitly renounced the search for the causes and natures of inanimate things, and confined himself to describing and correlating phenomena.[5] It was this approach which led to Newtonian mechanics and the new astronomy, to the new chemistry of Lavoisier and Dalton, and so to the immense amount of successful description and correlation that characterize the modern physical sciences. Ou authors appear to believe that these sciences are aiming at the same kinds of explanation as Aristotle, but that they have got somewhat

3 A. C. Crombie, *Robert Grosseteste and the Origins of Experimental Science* (Oxford, 1953).

4 J. H. Randall, 'The Development of Scientific Method in the School of Padua', *Journal of the History of Ideas*, I (1940), p. 177.

5 See quotations in A. C. Crombie, *Galileo's 'Dialogues concerning the two principal systems of the World'*, *Dominican Studies*, III (April-June 1950), pp. 105-138.

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off the track. But consideration of the actual method of the physical sciences and the history of their evolution suggests that they are aiming at a different kind of explanation, answering different questions and treating evidence from a different point of view.[6] The fruitful and permanent part of Aristotle's work in this field is his *philosophy of nature*, which should be clearly distinguished from natural science.[7]

The importance of the work to which this group of Dominicans has addressed itself is perhaps sufficiently shown by the fact that so deep a difference of opinion emerges (and is not concealed by the authors, in their account of the first week's debate) about the kind of explanation used in the physical sciences. The staff of this institute are doing an immense service in bringing together representatives of science and philosophy. They have done wisely in choosing to discuss the methods rather than the conclusions of science, thus avoiding traps into which many have fallen. Their enterprise deserves every support and the closest attention. Scientists have a great deal to learn from the Aristotelean tradition, particularly about the *presuppositions* of natural science—the differences between inanimate, organic, and intelligent beings, the causal order of the world, the role of sense-experience, and so on. If I have criticized parts of the present volume, it is because I think the attempted synthesis, including as it does suggestions for major re-orientations of sciences in which striking successes have been achieved, is premature, if not presumptuous. It would seem desirable first to consider more thoroughly the *de facto* methods and aims of the natural sciences today, to see how far they have been forced upon scientists by their subject-matter (formal object) and the techniques available; and to distinguish more clearly between natural sciences and philosophy of nature. A methodological synthesis would be an immense boon; it is a fundamental objective, and is probably the kind of intellectual integration to which we should look forward. But it will not come tomorrow, and a great deal of co-operative work must be done first. The Albertus Magnus Lyceum is in a position to make a vital contribution.

6 This incidentally was the view of that great Greek scholar, the late Professor Cornford; *cf.* his essay on 'Greek natural philosophy and modern science', in *The Unwritten Philosophy* (Cambridge, 1950).

7 This distinction is very clearly made, and applied to Aristotle's work, in a remarkable book by A. van Melsen, *Philosophy of Nature* (Pittsburgh, Duquesne University Press, 1953).