Science and Method
Introduction

Are the enterprises of the philosopher and the scientist distinct? In the past they were often closely intertwined, both being concerned with what there is in the world and how we are to understand it (compare introduction to Part II, above). Aristotle, one of the co-founders (with Plato) of Western philosophy, was also what we should now call a natural scientist – what used to be called a 'natural philosopher'. But although philosophy and science are closely related, they differ in focus. The philosopher of science is less occupied with the truth or falsity of particular theories than with a general investigation into the nature and justification of scientific activity itself. What is the relation between a scientific theory and the data which are supposed to confirm it? Can theories be conclusively proved (or disproved)? Can we justify the universal generalizations scientists make on the basis of necessarily limited data? What is meant by a cause, or a causal explanation? What are the respective roles of mathematical theory and empirical observation in science? Is science a 'purely rational' activity, to be assessed in terms of timeless standards of truth and validity, or can the theories of scientists only be understood within a particular historical and social context? These are some of the questions with which the philosopher of science is concerned; the extracts that follow trace some key landmarks in the quest for determining what is meant by a systematic scientific understanding of the world.

1 Four Types of Explanation: Aristotle, *Physics**

The achievements of Aristotle, both in science and in the philosophy of science, were formidably impressive and wide ranging; so much so that his ideas remained dominant throughout the Middle Ages and right up to the seventeenth century. In his *Posterior Analytics*, he laid down a model of scientific knowledge which strongly influenced subsequent thinking (see Part I, extract 3). But one of his most significant contributions, found both in his *Metaphysics*, and in his *Physics* (from which our first extract is taken), was his account of what it is to *explain* something. The fourfold structure he produced is often misleadingly called Aristotle's doctrine of 'the four causes'; in fact, a better name might be 'the four "becauses"', since the account maps out four ways in which we use the term 'because', or four ways in which we answer the question 'why?'

(1) 'Why is the bridge strong?' 'Because it is made of steel and concrete.' This type of answer gives what Aristotelians call the 'material cause' – an explanation in terms of the component parts or constituent ingredients. (2) 'Why is this stuff correctly classified as salt?' 'Because it is a compound of sodium and chloride.' This gives the Aristotelian 'formal cause' – an explanation in terms of the form, definition or essential properties of something. (3) 'Why did this baseball move?' 'Because someone struck it with a bat.' This gives the 'efficient cause' – an explanation in terms of what initiated or produced the relevant movement or change. (This is the sense in which the term 'cause' is most often used nowadays.) Finally, (4) 'Why does a row of sunflowers face east in the morning and gradually turn westward during the day?' 'To maximize the exposure to sunlight.' This last answer gives the 'final cause' (from the Latin *finis*, meaning 'end' or 'goal'); the explanation specifies, as Aristotle puts it, 'that for the sake of which' something is done. Notice that Aristotle lays great stress on this last type of cause, and he views much of the natural world as operating in terms of final causes, or (to use the more common expression nowadays) 'teleologically' (from the Greek *telos*, 'end' or 'goal'). As we shall see later on, the revolution which led to the emergence of modern science saw a systematic attack on the value and importance of this type of explanation in the sciences.

In one sense ['material cause'], that out of which a thing comes to be and which persists is called a 'cause', e.g. the bronze and the silver (and the kinds of things of which they are species) are the causes of a statue and a bowl respectively.

In another sense ['formal cause'], the form or original pattern is a cause – the account of what it is to be such and such (and the kind to which it belongs); for example, the ratio of two to one (and more generally, number) is the cause of an octave.

In another sense ['efficient cause'], the primary source of something's changing (or remaining as it is) is a cause. For example, the man who has deliberated is the cause (of his actions), the father is the cause of the child, and in general what makes something is the cause of what is made, and what produces change is the cause of what is changed.

In another sense ['final cause'], the end, or 'that for the sake of which' something is done is a cause. For example, health is the cause of a walk ('Why is he taking a walk?' Answer: 'In order to be healthy' – in saying this, we think we have given the cause.) The same applies to all the intermediate steps which are

* Aristotle, *Physics* [c.325 BC], Book II, ch. 3, ch. 8 (extracts); translation taken (with adaptations) from Aristotle, *Physica*, trans. R. P. Hardie and R. K. Gaye (Oxford: Clarendon, 1930).

brought about by the action of something else as a means towards the end; thus slimming, purging, drugs and surgical instruments are means towards health. All these things are 'for the sake of' the ends, though they differ from one another in that some are activities and others are instruments.

This then perhaps exhausts the number of ways in which the term 'cause' is used. As the word has several senses, it follows that one and the same thing can have several different causes (and not just incidentally). For example, both the art of the sculptor and the bronze are causes of the statue. These are causes of it not in so far as it is anything else, but causes of it *as a statue*; but they are not causes in the same way, since one is the material cause, and the other the efficient cause which is the source of the change. Some things can cause each other reciprocally; for example hard work is the cause of fitness and vice versa, but again not in the same way, since one is the cause as an end, and the other as a source of change . . .

But why should not nature work not *for the sake of* something, nor because it is *better* so, but just as the sky rains – not in order to make the corn grow, but out of necessity? What is drawn up must cool, and what has been cooled must become water and descend, the result of this being that the corn grows. Similarly if a man's crop is spoiled on the threshing floor, the rain did not fall 'for the sake of' this – in order that the crop might be spoiled, but the result just followed. Why then should it not be the same with the parts in nature, for example that our teeth should come up of necessity – the front teeth sharp, fitted for tearing, the molars broad and useful for grinding – not that they arose for this end, but it was merely a coincident result; and so with all the parts in which we suppose there is a purpose? Wherever all the parts came about just as they would have done if they had come to be for an end, such things survived, being organized spontaneously in a fitting way, whereas those which grew otherwise perished and continued to perish, as Empedocles says his 'man-faced ox-progeny' did.

Such are the arguments (and others of this kind) which may cause difficulty on this point. Yet it is impossible that this should be the true view. For teeth and all other natural things either invariably or normally come about in a given way; but this is not true of any of the results of chance or spontaneity. We do not ascribe to chance or mere coincidence the frequency of rain in winter, but we do just this in the case of frequent rain in summer; nor heat in the dog-days, but only if we have it in winter. If then it is agreed that things are either the result of coincidence or for an end, and these cannot be the result of coincidence of spontaneity, it follows that they must be for an end; and that such things are all due to nature even the champions of the theory under discussion would agree. Therefore action *for an end* is present in things which come to be, and are, by nature.

Further, where a series has a completion, all the previous steps are done for the sake of that. Now surely as in intelligent action, so in nature; and as in nature, so it is in each action, if nothing interferes. Now intelligent action is for the sake of an end; therefore the nature of things also is so. Thus if a house had been a thing made by nature, it would have been made in the same way as it is now by art; and if things made by nature were made also by art, they would come to be in the same way as by nature. So each step in the series is for the sake of the next; and

generally art partly completes what nature cannot bring to a finish, and partly imitates her. If, therefore, artificial products are for the sake of an end, so clearly also are natural products. The relation of the latter to the earlier terms of the series is the same in both.

This is most obvious in animals other than man: they make things neither by art nor after inquiry or deliberation. Hence people discuss whether it is by intelligence or by some other faculty that these creatures work – spiders, ants and the like. By gradual advance in this direction we come to see clearly that in plants too something is produced which is conducive to the end – for example leaves grow to produce shade for the fruit. If then it is both by nature and for an end that the swallow makes its nest and the spider its web, and plants grow leaves for the sake of the fruit and send their roots down (not up) for the sake of nourishment, it is plain that this kind of cause is operative in things which come to be and are by nature. And since 'nature' means two things, the matter and the form, of which the latter is the end, the form must be the cause in the sense of 'that for the sake of which'.

Now mistakes come to pass even in the operations of art: the grammarian makes a mistake in writing and the doctor pours out the wrong dose. Hence clearly mistakes are possible in the operations of nature also. If then in art there are cases in which what is rightly produced serves a purpose, and if where mistakes occur there was a purpose in what was attempted, only it was not attained, so must it be also in natural products, and monstrosities will be failures in the purposive effort. Thus when things were originally put together, the 'ox-progeny', if they failed to reach a determinate end, must have arisen through the corruption of some principle corresponding to what is now the seed . . .

It is absurd to suppose that the purpose is not present because we do not observe the agent deliberate. Art does not deliberate. If the shipbuilding art were present in the wood, it would produce the same results by nature. Hence if purpose is present in art, it is present in nature also. The best illustration is a doctor doctoring himself: nature is like that. It is plain then, that nature is a cause, a cause that operates for a purpose.

2 Experimental Methods and True Causes: Francis Bacon, *Novum Organum**

The 'revolution' which inaugurated the modern scientific age was in fact a long and sometimes tortuous process of change in the way human beings came to understand the natural world and how it should be interpreted. One of the heralds of that revolution was the English philosopher Francis Bacon, whose *Novum Organum* (the 'New Instrument' or 'New Method') was published in

* Francis Bacon, *Novum Organum* [1620]. Book I, §§ 1–3, 11–31, 36, 38–44, 46; Book II, §§ 1–3, 11–13, 15–16. From J. M. Robertson (ed.), *The Philosophical Works of Francis Bacon*, reprinted from the translation of Ellis and Spedding (London: Routledge, 1905), pp. 259–66, 302–3, 307–9, 315, 320. With omissions and minor modifications.