Introduction to the Philosophy of Science

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For Jacob

Foreword

An introduction to a topic hardly needs an introduction itself. My aim in this book has been simply to introduce students and others to the philosophy of science, and to do so in a balanced way. That is to say, I have tried to lay out some of the central philosophical problems raised by natural science so as to show what can be said on various sides of a given issue. In the first chapter I have indicated why I think the philosophy of science is important and what I take its scope to be.

I should like to thank Angela Blackburn of Oxford University Press for encouraging me to write this book and for her help with the writing. Intellectually I owe a considerable debt to a number of friends and colleagues who were kind enough to comment on what I had written: to Michael Redhead and Roger Scruton who commented on the whole manuscript, and to Donald Gillies and Graham Macdonald who went through particular chapters with me. The comments of an anonymous referee for Oxford University Press were also most helpful.

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I

Science as an Intellectual Activity

There is no institution in the modern world more prestigious than science. Nor is there an institution which, as a whole, is less controversial. It is true that there are those who object to some aspects of the contemporary applications of science, to the use of nuclear power, say, or to the side-effects of certain industrial products such as the private motor car. But those who protest about such things are usually quite happy to have their messages transmitted by the latest audio-visual technology and their persons conveyed by high-speed train or plane. And in a thousand and one other ways, their lives are unthinkingly dependent on devices which have been made possible only in the last two or three hundred years and only through scientific discoveries. There can hardly be more than a handful of people all over the world who would actually choose to live completely without electricity or antibiotics or synthetic fibres or plastics or radio or mechanical transport or electronics. In this sense, then, science and its discoveries are deeply uncontroversial: at a practical level they form the unquestioned horizons within which the vast majority of mankind live or would like to live. Objections to science and scientific research tend to be partial, to *some* aspects of the application of scientific knowledge, leaving unquestioned most of its applications. They also tend to be (in the bad sense) theoretical, affecting the way people talk rather than the way they actually live.

As well as informing the way we live, the discoveries of science cut across political and religious divisions to a considerable extent. Again this is partly to do with the effectiveness in application of scientific discoveries. Most citizens of most states want the material benefits scientific discoveries make possible, even when they want other things as well. Rulers and political leaders are by now thoroughly intimidated by hearing about Hitler's failure to get the atomic bomb owing to his objections to 'Jewish' science (which was supposed to underlie nuclear physics) and about the disastrous effects on Russian agriculture of the ideologically orthodox but biologically incorrect theories of T. D. Lysenko. And, of course, they are right to be so intimidated: science does cut through political ideology, because its theories are about nature, and made true or false by a non-partisan nature, whatever the race or beliefs of their inventor, and however they conform or fail to conform to political or religious opinion. In a world in which technological success is crucial to any regime, no sane leader is going to jeopardize his or her chances by interfering with scientific research or its applications on ideological grounds.

As I will suggest in the final chapter of this book, not everything one finds in writings critical of 'science' or 'the scientific mentality' is completely misguided. There are certainly areas of human life—the most important areas, in fact—about which science as such can have nothing to tell us, and where the application of methods analogous to those of science can only be harmful. But because of the importance of science and of these questions it is important to be balanced and honest in what one says about science, and to recognize both our dependence on it and its very real intellectual and moral merits.

On our dependence on science, it is simply not possible for the present population of the world to be supported at all, let alone enjoy a comfortable standard of existence with a reasonable life expectancy, without reliance on many of the discoveries of modern science. It should be obvious that there are not the space or resources in the world for a general return to nature. Just how we use technology, though, and

just which technologies we attempt to develop are in a broad sense political questions, which require ethical and political decisions, and may be hotly debated. But debating such issues does not entail a globally anti-scientific stance, and those opposed to aspects of the nuclear industry, say, or to genetic engineering do their cause no good at all by adopting such a stance. Science is too prestigious to make global anti-science seem reasonable or politically attractive. The prestige of science is not mere propaganda, but derives in part from the solid realization people pre-theoretically have of its benefits and of its pervasiveness in the lives of us all. On a more theoretical level, though, its prestige stems from the way knowledge grows in science in contrast to what happens to other fields of knowledge, and from what is taken to be the objectivity of its claims.

In this book, we shall be mainly concerned to see how far science deserves its prestige on this theoretical level; we will attempt to see how far it can genuinely claim to present us with more and more true knowledge about the nature of the world. And for this, we shall have to concentrate mainly on the theories of science, rather than on its technological applications. For if true knowledge is growing in science, this means that the theories of science must be giving us more and more truths about the world.

Growth of Knowledge

In a perfectly obvious sense, over the last four hundred years or so there has been progress in science. Measurement of physical quantities becomes more precise, previously unknown particles and substances are discovered, new effects are produced and applied. Even if the ancients were wiser than us, and knew better how to live, they did not know the speed of light or the mass of the earth or the structure of the hydrogen atom or how to produce and apply lasers or the photo-electric effect. And we know now that, despite the brilliance of many of the observations, most of the theories of the universe expounded in Aristotle's writings are quite simply false. The earth is not the centre of the universe, nor do heavy bodies seek the centre of the earth as their natural resting-place, nor is the earth surrounded by series of concentric circles on which the other heavenly bodies revolve.

There is a striking contrast here between the development of modern science and the arts. No one would say of a work of music or literature that it was better than an earlier work just because it was later. A recent work by Luciano Berio is not, because of its modernity, better than Beethoven's Violin Concerto, and, it would be just as hard to say that Brahms's Violin Concerto was better than Beethoven's. In contrast to the development of theories in modern science, a later masterpiece in a given artistic genre is not thereby better than an earlier one, nor does it necessarily attain the aim of the genre better, or anything of that sort. Indeed, in the case of violin concertos, it would be hard if not actually senseless to specify a target at which all violin concertos are aiming, and in relation to which one could say that concerto A got nearer to the target than concerto B. Leaving Berio aside, it hardly makes sense to say of the Beethoven and the Brahms that one is better than the other. There just is no scale on which one could judge such things, once a certain level of expressive adequacy has been reached.

The case with scientific theories, though, is quite different. Here we are able to specify a clear target at which all theories aim, and we often have confidence that theory A has got closer to the target than theory B. The aim might be characterized as discovering the truth about the natural world, and when we have theories which aim to describe the same bits of the natural world we can often say that a later theory is better than an earlier. Thus, Copernicus's heliocentric picture of the universe was better than Aristotle's geocentric picture, and Newton provided a better account of

the solar system and the universe than either. Similarly, every schoolchild now knows that the chemist Joseph Priestley mistakenly thought he had identified a substance he called 'phlogiston', a gaseous fluid with possibly negative weight which, among many other things, was given off when metals burned. We now know that there is no such thing and that there is no one substance that does all the things phlogiston had been supposed to do. Priestley had actually been observing the effects of oxygen, which metals absorb from the air when burned, rather than those of the phlogiston they were supposed to give off. When he imagined he had isolated a sample of dephlogisticated air, he had actually produced oxygen.

As I say, this story about Priestley and phlogiston is something every schoolchild knows and in that sense, every schoolchild has knowledge Priestley did not have, and in that sense is in advance of Priestley. But it is not the case that every schoolchild is a better chemist than Priestley, any more than Berio or even Brahms is a better composer than Beethoven. We can speak of an objective advance or progress in the one case but not in the other because we can speak unambiguously of knowledge having grown in the sciences, so that those working later in a given field of science, by that very fact alone, may be said to know more than their predecessors.

Apparently rather against the grain of what I have just been saying, T. S. Eliot once remarked that in literature we know far more than our predecessors because what we know is their work. Growth of knowledge in science, though, is not at all like that, and this is another way of bringing out the distinction I am drawing between science and the arts. Although a few stories from the history of science, like that of Priestley and phlogiston, are part of the folklore of the subject, most workers in a scientific field do not know the history of their field in any depth or detail. They do not have to know it, because the history of science will consist largely of theories that have been discarded, and which are regarded as giving far less true information about the world than their successors. An astronomer will tell you what, in the considered view of astronomers today, the universe is like, not what Aristotle or Copernicus thought it was like. The theories of Aristotle and Copernicus are, from the scientific point of view, dead; we have progressed beyond them and there is no need to revive them except as historical curiosities we may briefly contrast with present knowledge. The case is quite different with works of art and literature. The dead writers of whom Eliot spoke are part of the soil and tradition in which we live, and we deepen and refresh our understanding both of ourselves and of art by returning to them and deepening our acquaintance with them.

Objectivity and the External World

The reason why we in doing science have no need to return to past science is because the theories of science are not about human endeavour or human expressiveness. Human self-expression and understanding is a cumulative, historical process in which where we are now and what we now think of ourselves is rooted in the forms of life and expression developed in the past, and will always involve some coming to terms with our history and our past. But a scientific theory will, by contrast, be dealing with a world independent of human history and human intervention. The truths science attempts to reveal about atoms and the solar system and even about microbes and bacteria would still be true even if human beings had never existed. As we have noted, it is a humanly impartial ahistorical nature that decrees the truth or falsity of scientific theories, and it does so without regard to religious or political rectitude.

This brings us to one of the distinctive features of scientific activity, which morally and humanly is one of its great strengths. The impartiality of nature to our feelings, beliefs,

and desires means that the work of testing and developing scientific theories is insensitive to the ideological background of individual scientists. A scientific theory will characteristically attempt to explain some natural phenomena by producing some general formula or theory covering all the phenomena of that particular type. From this general formula, it will be possible to predict how future phenomena in the class in question will turn out. Whether they do or not will depend on nature rather than on men, and any scientist can observe whether they do or not, regardless of his other beliefs.

To take a concrete example, Newton produced a set of formulae which give us a general account of the motions of bodies, showing how these motions are affected by such things as force, mass, acceleration, and gravitational attraction. Among other things, these formulae explained the courses the various planets took in orbit around the sun. From Newton's formulae, it was possible to predict the future behaviour of the planets that were already known, and, as it turned out, the very existence of planets unknown in Newton's time. We now know that Newton himself had all sorts of theological and mystical concerns, and that these may well have inspired his search for general mathematical formulae uniting events on earth and in the heavens. But his theories were intelligible to people who did not share these concerns, and his predictions were testable by anyone who knew how to make the appropriate observations, regardless of their ideology, race, or upbringing. You do not have to share Newton's outlook in any way, in order to come to a reasoned assessment of the truth or otherwise of his theories, for the observations relevant to such assessments are of a world not created by us, the perception of which does not crucially depend on one's ideological standpoint. The case is quite otherwise with some of the grand theories of psychology and the social sciences, where critics are sometimes told that their criticisms are invalid because their observations are distorted by their being sexually repressed (as in the case of Freudianism) or because they are not identifying themselves with the proletariat (as in the case of Marxism). But, because of the nature of the enterprise, the scientific community is non-sectarian and its work cuts across all sorts of human divisions. There is no such thing as British science, or Catholic science, or Communist science, though there are Britons, Catholics, and Communists who are scientists, and who should, as scientists, be able to communicate fully with each other. The ideological or religious background of a scientist becomes important only when, as with a doctrinaire Marxist-Leninist like Lysenko or some fundamentalist Christians, non-scientific beliefs make disinterested scientific enquiry impossible.

Prediction and Explanation

In the previous section it was asserted that the theories of science characteristically take the form of general mathematical formulae covering a particular range of types of event, from which it is possible to deduce predictions of specific events. Newton's laws, for example, give us general formulae concerning the motions and mutual attraction and repulsion of heavy bodies, from which we can predict such things as solar eclipses. From the standpoint of modern science, there is a close connection between the notions of prediction and explanation. If you can produce general formulae allowing you to make mathematically precise predictions of a class of specific states of affairs, you will generally have gone a good way to providing an explanation of those states of affairs. To take another example, the classical gas law tells us that the volume of any body of gas is a function of its temperature and pressure ($V = c.T/P$, where c is a constant factor). Applying this formula to specific bodies of gas, with particular temperatures and pressures which we measure, enables us to predict their actual volumes; in thus reaching a prediction of a

specific instance on the basis of a general formula covering all instances of a given type, it is quite natural to think we have explained the relevant characteristics of the specific instance.

One reason for not saying here that we have *always* gone some way to producing an explanation when we are able to make predictions on the basis of general formulae is that there are cases discussed in the philosophical literature in which one is enabled to produce a precise prediction of states of affairs on the basis of a general theory without—it is alleged—being tempted to say that one has any sort of explanation before one. Thus, for example, by invoking Pythagoras's theorem, one can predict the distance of a mouse from an owl, when all we knew was that the mouse was four feet from a three-foot flag-pole on top of which was an owl; but, it is said, one would not want to say that the theorem explained the distance of the mouse from the owl. Against this example it might be said that there was no genuine prediction here, in the sense of an inference from a past state of affairs to a future one, as opposed to a move from a state of past ignorance to one of future knowledge. It is not clear, though, that all scientific explanations do involve predictions from past states of affairs to future ones, rather than predictions about what one will find on the basis of existing knowledge, for this latter type of reasoning is involved when people deduce conclusions concerning the nature of the big bang from their cosmological theories and their knowledge of the current state of the universe. The predictions by which one tests such speculation may well be predictions about what one will find when one probes traces of past events. However, given that we are prepared to work with a concept of prediction which is wide enough to encompass the prediction and discovery of as yet unknown facts, including facts about the past, it is certainly the case that we now expect scientific explanations to have predictive power. We can say this even though there may be cases, like that involving the Pythagoras theorem, when we can make predictions, or at least deduce as yet unknown facts, on the basis of general theories, without wanting to speak of an explanation of those facts. The reason why many criticize Freudians and Marxists for being unscientific is precisely because their theories either lead to no specific predictions at all or to predictions that are false. Making predictions on the basis of one's theories is, then, a necessary if not sufficient condition for a genuine scientific explanation.

The notion of a scientific explanation was not always linked so closely to its mathematical and predictive power. In the science associated with Aristotle and his followers, giving an explanation of a phenomenon consisted in delineating its essence, or essential properties, and in showing why, in order to fulfil its function or nature, it had to have those properties. Fire rose, for example, in order that it should reach its natural resting-place, which was taken to be a spherical shell just inside the orbit of the moon. The essence of fire, being a light body, was to rise. It does so in order to fulfil its nature.

From the modern scientific viewpoint there are at least two things wrong with this 'essentialist' type of explanation. In the first place, we have no justification for imputing purposes to natural phenomena like fire or planets or heavy bodies. Their activity is conditioned by the forces that act upon them, their underlying structure, and the interaction of the two. They do not have any ulterior purposes, or essential nature they are trying to fulfil. Secondly, there is nothing in a typical Aristotelian explanation about precise quantities or measurements. They give us reasons (of a sort) for why things happen, but not the precise amounts or distances or times involved. And these precise measurements are crucial for modern science, because they are required for the formulation and application of its theories.

It is easy to see why the shift occurred from Aristotelian essentialist explanations to the mathematical-predictive explanations of modern science. If you want to control and manipulate phenomena, then what you need to know are the

precise conditions in which effects of given sort occur. If you are working with a piece of metal, you want to know just how much it will expand under given degrees of heat. You do not want to be told that its expansion is due to the fact that it has to expand in order to fulfil its nature. And, as we shall see in the next chapter, modern science is very much about controlling nature, hence its tendency to elide prediction and explanation, and the reason why its predictions will characteristically, if not universally, be predictions about states of affairs which have not yet happened.

Yet, even at this point, one might feel that there is something to be said for a more meaty type of explanation than appears to be given in simply producing formulae for prediction. Newton himself gave expression to this feeling when, at the end of his *Mathematical Principles*, he said that while he had demonstrated the reality of gravity and its effects—by precise mathematical methods, we would stress—he had not yet been able to explain the cause of these effects. It is as if a purely mathematical correlation of events, saying, for example, that the gravitational force on such and such an object will be so and so in such and such circumstances, stays too much on the surface of things, and fails to give us insight into the underlying structure of gravitational phenomena or of the essence of gravity. We shall take this point up again in Chapters 3, 5, and 6, when we consider whether a full scientific explanation is *more* than a device for predicting effects in the natural world. But we have just seen a good reason for thinking it must be at least that.