THE PHILOSOPHY OF SCIENCE

An Introduction

by

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4.7 *Do sub-microscopic entities exist?*

Non-scientists are often puzzled to know whether the electrons, genes and other entities scientists talk about are to be thought of as really existing or not. Scientists themselves also have some difficulty in saying exactly where they stand on this issue. Some are inclined to insist that all these things are just as real, and exist in the same sense as tables and chairs and omnibuses. But others feel a certain embarrassment about them, and hesitate to go so far; they notice the differences between establishing the existence of electrons from a study of electrical phenomena, inferring the existence of savages from depressions in the sand, and inferring the existence of an inflamed appendix from a patient's signs and symptoms; and it may even occur to them that to talk about an electromagnet in terms of 'electrons' is a bit like talking of Pyrexia of Unknown Origin when the patient has an unaccountable temperature. Yet the theory of electrons does *explain* electrical phenomena in a way in which no mere translation into jargon, like 'pyrexia', can explain a sick man's temperature; and how, we may ask, could the electron theory work at all if, after all, electrons did not really exist?

Stated in this way, the problem is confused: let us therefore scrutinize the question itself a little more carefully. For when we compare Robinson Crusoe's discovery with the physicist's one, it is not only the sorts of discovery which are different in the two cases. To talk of existence in both cases involves quite as much of a shift, and by passing too swiftly from one use of the word to the other we may make the problem unnecessarily hard for ourselves.

Notice, therefore, what different ideas we may have in mind when we talk about things 'existing'. If we ask whether dodos exist or not, i.e. whether there are any dodos left nowadays, we are asking whether the species has survived or is extinct. But when we ask whether electrons exist or not, we certainly do not have in mind the possibility that they may have become extinct: in whatever sense we ask this question, it is not one in which 'exists' is opposed to 'does not exist any more'. Again, if we ask whether Ruritania exists, i.e. whether there is such a country as

Ruritania, we are asking whether there really is such a country as Ruritania or whether it is an imaginary, and so a non-existent country. But we are not interested in asking of electrons whether they are genuine instances of a familiar sort of thing or non-existent ones: the way in which we are using the term 'exist' is not one in which it is opposed to 'are non-existent'. In each case, the word 'exist' is used to make a slightly different point, and to mark a slightly different distinction. As one moves from Man Friday to dodos, and on from them to Ruritania, and again to electrons, the change in the nature of the cases brings other changes with it: notably in the way one has to understand sentences containing the word 'exist'.

What, then, of the question, "Do electrons exist?" How is this to be understood? A more revealing analogy than dodos or Ruritania is to be found in the question, "Do contours exist?" A child who had read that the equator was 'an imaginary line drawn round the centre of the earth' might be struck by the contours, parallels of latitude and the rest, which appear on maps along with the towns, mountains and rivers, and ask of them whether *they* existed. How should we reply? If he asked his question in the bare words, "Do contours exist?", one could hardly answer him immediately: clearly the only answer one can give to this question is "Yes and No." They 'exist' all right, but do they *exist*? It all depends on your manner of speaking. So he might be persuaded to restate his question, asking now, "Is there really a line on the ground whose height is constant?"; and again the answer would have to be "Yes and No", for there is (so to say) a 'line', but then again not what you might call a *line*. . . . And so the cross-purposes would continue until it was made clear that the real question was: "Is there anything to show for contours—anything visible on the terrain, like the white lines on a tennis court? Or are they only cartographical devices, having no geographical counterparts?" Only then would the question be posed in anything like an unambiguous manner. The sense of 'exists' in which a child might naturally ask whether contours existed is accordingly one in which 'exists' is opposed not to 'does not exist any more' or to 'is non-existent', but to 'is only a (cartographical) fiction'.

This is very much the sense in which the term 'exists' is used of atoms, genes, electrons, fields and other theoretical entities in the physical sciences. There, too, the question "Do they exist?" has in practice the force of "Is there anything to show for them, or are they only theoretical fictions?" To a working physicist, the question "Do neutrinos exist?" acts as an invitation to 'produce a neutrino', preferably by making it *visible.* If one could do this one would indeed have something to show for the term 'neutrino', and the difficulty of doing it is what explains the peculiar difficulty of the problem. For the problem arises acutely only when we start asking about the existence of *sub-microscopic* entities, i.e. things which by all normal standards are invisible. In the nature of the case, to produce a neutrino must be a more sophisticated business than producing a dodo or a nine-foot man. Our problem is accordingly complicated by the need to decide what is to count as 'producing' a neutrino, a field or a gene. It is not obvious what sorts of thing ought to count: certain things are, however, generally regarded by scientists as acceptable—for instance, cloud-chamber pictures of α-ray tracks, electron microscope photographs or, as a second-best, audible clicks from a Geiger counter. They would regard such striking demonstrations as these as sufficiently like being shown a live dodo on the lawn to qualify as evidence of the existence of the entities concerned. And certainly, if we reject these as insufficient, it is hard to see what more we can reasonably ask for: if the term 'exists' is to have any application to such things, must not this be it?

What if no such demonstration were possible? If one could not show, visibly, that neutrinos existed, would that necessarily be the end of them? Not at all; and it is worth noticing what happens when a demonstration of the preferred type is not possible, for then the difference between talking about the existence of electrons or genes, and talking about the existence of dodos, unicorns or nine-foot men becomes all-important. If, for instance, I talk plausibly about unicorns or nine-foot men and have nothing to show for them, so that I am utterly unable to say, when challenged, under what circumstances a specimen might be, or might have been seen, the conclusion may reasonably be drawn that my nine-foot men are imaginary and my unicorns a myth. In either case, the things I am talking about may be presumed to be non-existent, i.e. are discredited and can be written off. But in the case of atoms, genes and the like, things are different: the failure to bring about or describe circumstances in which one might point and say, "There's one!", need not, as with unicorns, be taken as discrediting them.

Not all those theoretical entities which cannot be shown to exist need be held to be non-existent: there is for them a middle way. Certainly we should hesitate to assert that any theoretical entity really existed until a photograph or other demonstration had been given. But, even if we had reason to believe that no such demonstration ever could be given, it would be too much to conclude that the entity was non-existent; for this conclusion would give the impression of discrediting something that, as a fertile explanatory concept, did not necessarily deserve to be discredited. To do so would be like refusing to take any notice of contour lines because there were no visible marks corresponding to them for us to point to on the ground. The conclusion that the notion must be dropped would be justified only if, like 'phlogiston', 'caloric fluid' and the 'ether', it had also lost all explanatory fertility. No doubt scientists would be happy if they could refer in their explanations only to entities which could be shown to exist, but at many stages in the development of science it would have been crippling to have insisted on this condition too rigorously. A scientific theory is often accepted and in circulation for a long time, and may have to advance for quite a long way, before the question of the real existence of the entities appearing in it can even be posed.

The history of science provides one particularly striking example of this. The whole of theoretical physics and chemistry in the nineteenth century was developed round the notions of atoms and molecules: both the kinetic theory of matter, whose contribution to physics was spectacular, and the theory of chemical combinations and reactions, which turned chemistry into an exact science, made use of these notions, and could hardly have been expounded except in terms of them. Yet not until 1905 was it definitively shown by Einstein that the phenomenon of Brownian motion could be regarded as a demonstration that atoms and molecules really existed. Until that time, no such demonstration had ever been recognized, and even a Nobel prize-winner like Ostwald, for whose work as a chemist the concepts 'atom' and 'molecule' must have been indispensable, could be sceptical until then about the reality of atoms. Moreover by 1905 the atomic theory had ceased to be the last word in physics: some of its foundations were being severely attacked, and the work of Niels Bohr and J. J. Thomson was beginning to alter the physicist's whole picture of the constitution of matter. So, paradoxically, one finds that the major triumphs of the atomic theory were achieved at a time when even the greatest scientists could regard the idea of atoms as hardly more than a useful fiction, and that atoms were definitely shown to exist only at a time when the classical atomic theory was beginning to lose its position as the basic picture of the constitution of matter.

Evidently, then, it is a mistake to put questions about the reality or existence of theoretical entities too much in the centre of the picture. In accepting a theory scientists need not, to begin with, answer these questions either way: certainly they do not, as Kneale suggests, commit themselves thereby to a belief in the existence of all the things in terms of which the theory is expressed. To suppose this is a variant of the Man Friday fallacy. In fact, the question whether the entities spoken of in a theory exist or not is one to which we may not even be able to give a meaning until the theory has some accepted position. The situation is rather like that we encountered earlier in connexion with the notion of light travelling. It may seem natural to suppose that a physicist who talks of light as travelling must make some assumptions about what it is that is travelling: on investigation, however, this turns out not to be so, for the question, what it is that is travelling, is one which cannot even be asked without going beyond the phenomena which the notion is originally used to explain. Likewise, when a scientist adopts a new theory, in which novel concepts are introduced (waves, electrons or genes), it may seem natural to suppose that he is committed to a belief in the existence of the things in terms of which his explanations are expressed. But again, the question whether genes, say, really exist takes us beyond the original phenomena explained in terms of 'genes'. To the scientist, the real existence of his theoretical entities is contrasted with their being only useful theoretical fictions: the fact of an initial explanatory success may therefore leave the question of existence open.

There is a converse to this form of the Man Friday fallacy. Having noticed that a theory may be accepted long before visual demonstrations can be produced of the existence of the entities involved, we may be tempted to conclude that such things as cloud-chamber photographs are rather overrated: in fact, that they only seem to bring us nearer to the things of which the physicist speaks as a result of mere illusion. This is a conclusion which Kneale has advanced, on the ground that physical theories do not stand or fall by the results obtained from cloud-chambers and the like rather than by the results of any other physical experiments. But this is still to confuse two different questions, which may be totally independent: the question of the acceptability of the theories and the question of the reality of the theoretical entities. To regard cloud-chamber photographs as showing us that electrons and α-particles really exist need not mean giving the cloud-chamber a preferential status among our grounds for accepting current theories of atomic structure. These theories were developed and accepted before the cloud-chamber was, or indeed could have been invented. Nevertheless, it was the cloud-chamber which first showed in a really striking manner just how far nuclei, electrons, α-particles and the rest could safely be thought of as real things; that is to say, as more than explanatory fictions.