

# REPRESENTING AND INTERVENING

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INTRODUCTORY TOPICS IN THE PHILOSOPHY OF  
NATURAL SCIENCE

IAN HACKING

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*For Rachel*

'Reality . . . what a concept' – S. V.

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My chief lesson here is that at least some scientific realism can use the word 'real' very much the same way that Austin claims is standard. The word is not notably ambiguous. It is not particularly deep. It is a substantive-hungry trouser-word. It marks a contrast. What contrast it marks depends upon the noun or noun phrase *N* that it modifies or is taken to modify. Then it depends upon the way that various candidates for being *N* may fail to be *N*. If the philosopher is suggesting a new doctrine, or a new context, then one will have to specify why lines of force, or the id, fail to be real entities. Smart says entities are for building. Cartwright says they are for causing. Both authors will deny, although for different reasons, that various candidates for being real entities are, in fact, real. Both are scientific realists about some entities, but since they are using the word 'real' to effect different contrasts, the contents of their 'realisms' are different. We shall now see that the same thing can happen for anti-realists.

### 3 Positivism

One anti-realist tradition has been around for a long time. At first sight it does not seem to worry about what the word 'real' means. It says simply: there *are* no electrons, nor any other theoretical entities. In a less dogmatic mood it says we have no good reason to suppose that any such things exist; nor have we any expectation of showing that they do exist. Nothing can be known to be real except what might be observed.

The tradition may include David Hume's *A Treatise of Human Nature* (1739). Its most recent distinguished example is Bas van Fraassen's *The Scientific Image* (1980). We find precursors of Hume even in ancient times, and we shall find the tradition continuing long into the future. I shall call it *positivism*. There is nothing in the name, except that it rings a few bells. The name had not even been invented in Hume's day. Hume is usually classed as an empiricist. Van Fraassen calls himself a constructive empiricist. Certainly each generation of philosophers with a positivist frame of mind gives a new form to the underlying ideas and often chooses a new label. I want only a handy way to refer to those ideas, and none serves me better than 'positivism'.

#### Six positivist instincts

The key ideas are as follows: (1) *An emphasis upon verification* (or some variant such as *falsification*): Significant propositions are those whose truth or falsehood can be settled in some way. (2) *Pro-observation*: What we can see, feel, touch, and the like, provides the best content or foundation for all the rest of our non-mathematical knowledge. (3) *Anti-cause*: There is no causality in nature, over and above the constancy with which events of one kind are followed by events of another kind. (4) *Downplaying explanations*: Explanations may help organize phenomena, but do not provide any deeper answer to *Why* questions except to say that the phenomena regularly occur in such and such a way. (5) *Anti-theoretical entities*:

Positivists tend to be non-realists, not only because they restrict reality to the observable but also because they are against causes and are dubious about explanations. They won't infer the existence of electrons from their causal effects because they reject causes, holding that there are only constant regularities between phenomena. (6) Positivists sum up items (1) to (5) by being *against metaphysics*. Untestable propositions, unobservable entities, causes, deep explanation – these, says the positivist, are the stuff of metaphysics and must be put behind us.

I shall illustrate versions of these six themes by four epochs: Hume (1739), Comte (1830–42), logical positivism (1920–40) and van Fraassen (1980).

### Self-avowed positivists

The name 'positivism' was invented by the French philosopher Auguste Comte. His *Course of Positive Philosophy* was published in thick installments between 1830 and 1842. Later he said that he had chosen the word 'positive' to capture a lot of values that needed emphasis at the time. He had, he tells us, chosen the word 'positive' because of its happy connotations. In the major West European languages 'positive' had overtones of reality, utility, certainty, precision, and other qualities that Comte held in esteem.

Nowadays when philosophers talk of 'the positivists' they usually mean not Comte's school but rather the group of logical positivists who formed a famous philosophy discussion group in Vienna in the 1920s. Moritz Schlick, Rudolf Carnap, and Otto Neurath were among the most famous members. Karl Popper, Kurt Gödel, and Ludwig Wittgenstein also came to some of the meetings. The Vienna Circle had close ties to a group in Berlin of whom Hans Reichenbach was a central figure. During the Nazi regime these workers went to America or England and formed a whole new philosophical tradition there. In addition to the figures that I have already mentioned, we have Herbert Feigl and C.G. Hempel. Also the young Englishman A.J. Ayer went to Vienna in the early 1930s and returned to write his marvellous tract of English logical positivism, *Language, Truth and Logic* (1936). At the same time Willard V.O. Quine made a visit to Vienna which sowed the seeds of his doubt about some logical positivist theses, seeds which blossomed into Quine's famous denials of the analytic–synthetic

distinction and the doctrine of the indeterminacy of translation.

Such widespread influence makes it natural to call the logical positivists simply positivists. Who remembers poor old Comte, longwinded, stuffy, and not a success in life? But when I am speaking strictly, I shall use the full label 'logical positivism', keeping 'positivism' for its older sense. Among the distinctive traits of logical positivism, in addition to items (1) to (6), is an emphasis on logic, meaning, and the analysis of language. These interests are foreign to the original positivists. Indeed for the philosophy of science I prefer the old positivism just because it is not obsessed by a theory of meaning.

The usual Oedipal reaction has set in. Despite the impact of logical positivism on English-speaking philosophy, no one today wants to be called a positivist. Even logical positivists came to favour the label of 'logical empiricist.' In Germany and France 'positivism' is, in many circles, a term of opprobrium, denoting an obsession with natural science and a dismissal of alternative routes to understanding in the social sciences. It is often wrongly associated with a conservative or reactionary ideology.

In *The Positivist Dispute in German Sociology*, edited by Theodore Adorno, we see German sociology professors and their philosophical peers – Adorno, Jürgen Habermas and so forth – lining up against Karl Popper, whom they call a positivist. He himself rejects that label because he has always dissociated himself from logical positivism. Popper does not share enough of my features (1) to (6) for me to call him a positivist. He is a realist about theoretical entities, and he holds that science tries to discover explanations and causes. He lacks the positivist obsession with observation and the raw data of sense. Unlike the logical positivists he thought that the theory of meaning is a disaster for the philosophy of science. True, he does define science as the class of testable propositions, but far from decrying metaphysics, he thinks that untestable metaphysical speculation is a first stage in the formation of more testable bold conjectures.

Why then did the anti-positivist sociology professors call Popper a positivist? *Because he believes in the unity of scientific method.* Make hypotheses, deduce consequences, test them: that is Popper's method of conjecture and refutation. He denies that there is any peculiar technique for the social sciences, any *Verstehen* that is

different from what is best for natural science. In this he is at one with the logical positivists. But I shall keep 'positivism' for the name of an anti-metaphysical collection of ideas (I) to (6), rather than dogma about the unity of scientific methodology. At the same time I grant that anyone who dreads an enthusiasm for scientific rigour will see little difference between Popper and the members of the Vienna Circle.

### Anti-metaphysics

Positivists have been good at slogans. Hume set the tone with the ringing phrases with which he concludes his *An Enquiry Concerning Human Understanding*:

When we run over libraries, persuaded of these principles, what havoc must we make? If we take in our hand any volume; of divine or school metaphysics, for instance; let us ask, *Does it contain any abstract reasoning concerning quantity or number?* No. *Does it contain any experimental reasoning concerning matter of fact and existence?* No. Commit it then to the flames: for it can contain nothing but sophistry and illusion.

In the introduction to his anthology, *Logical Positivism*, A.J. Ayer says that this 'is an excellent statement of the positivists' position. In the case of the logical positivists the epithet "logical" was added because they wished to annex the discoveries of modern logic.' Hume, then, is the beginning of the criterion of verifiability intended to distinguish nonsense (metaphysics) from sensible discourse (chiefly science). Ayer began his *Language, Truth and Logic* with a powerful chapter, called 'The elimination of metaphysics'. The logical positivists, with their passion for language and meanings, combined their scorn for idle metaphysics with a meaning-oriented doctrine called 'the verification principle'. Schlick announced that the meaning of a statement is its method of verification. Roughly speaking, a statement was to be meaningful, or to have 'cognitive meaning', if and only if it was verifiable. Surprisingly, no one was ever able to define verifiability so as to exclude all bad metaphysical conversation and include all good scientific talk.

Anti-metaphysical prejudices and a verification theory of meaning are linked largely by historical accident. Certainly Comte was a great anti-metaphysician with no interest in the study of 'meanings'. Equally in our day van Fraassen is as opposed to metaphysics.

He is of my opinion that, whatever be the interest in the philosophy of language, it has very little value for understanding science. At the start of *The Scientific Image*, he writes: 'My own view is that empiricism is correct, but could not live in the linguistic form the [logical] positivists gave it.' (p. 3)

### Comte

Auguste Comte was very much a child of the first half of the nineteenth century. Far from casting empiricism into a linguistic form, he was an historicist: that is, he firmly believed in human progress and in the near-inevitability of historical laws. It is sometimes thought that positivism and historicism are at odds with each other: quite the contrary, they are, for Comte, complementary parts of the same ideas. Certainly historicism and positivism are no more necessarily separated than positivism and the theory of meaning are necessarily connected.

Comte's model was a passionate *Essay on the Development of the Human Mind*, left as a legacy to progressive mankind by the radical aristocrat, Condorcet (1743–94). This document was written just before Condorcet killed himself in the cell from which, the following morning, he was to be taken to the guillotine. Not even the Terror of the French Revolution, 1794, could vanquish faith in progress. Comte inherited from Condorcet a structure of the evolution of the human spirit. It is defined by The Law of Three Stages. First we went through a theological stage, characterized by the search for first causes and the fiction of divinities. Then we went through a somewhat equivocal metaphysical stage, in which we gradually replaced divinities by the theoretical entities of half-completed science. Finally we now progress to the stage of positive science.

Positive science allows propositions to count as true-or-false if and only if there is some way of settling their truth values. Comte's *Course of Positive Philosophy* is a grand epistemological history of the development of the sciences. As more and more styles of scientific reasoning come into being, they thereby constitute more and more domains of positive knowledge. Propositions cannot have 'positivity' – be candidates for truth-or-falsehood – unless there is some style of reasoning which bears on their truth value and can at least in principle determine that truth-value. Comte, who invented

the very word 'sociology', tried to devise a new methodology, a new style of reasoning, for the study of society and 'moral science'. He was wrong in his own vision of sociology, but correct in his meta-conception of what he was doing: creating a new style of reasoning to bring positivity – truth-or-falsehood – to a new domain of discourse.

Theology and metaphysics, said Comte, were earlier stages in human development, and must be put behind us, like childish things. This is not to say that we must inhabit a world denuded of values. In the latter part of his life Comte founded a Positivist Church that would establish humanistic virtues. This Church is not quite extinct; some buildings still stand, a little tatty, in Paris, and I am told that Brazil still possesses strongholds of the institution. Long ago it did flourish in collaboration with other humanistic societies, in many parts of the world. Thus positivism was not only a philosophy of scientism but a new, humanistic, religion.

#### Anti-cause

Hume notoriously taught that cause is only constant conjunction. To say that *A* caused *B* is not to say that *A*, from some power or character within itself, brought about *B*. It is only to say that things of type *A* are regularly followed by things of type *B*. The details of Hume's argument are analysed in hundreds of philosophy books. We may, however, miss a good deal if we read Hume out of his historical context.

Hume is in fact not responsible for the widespread philosophical acceptance of a constant-conjunction attitude to causation. Isaac Newton did it, unintentionally. The greatest triumph of the human spirit in Hume's day was held to be the Newtonian theory of gravitation. Newton was so canny about the metaphysics of gravity that scholars will debate to the end of time what he really thought. Immediately before Newton, all progressive scientists thought that the world must be understood in terms of mechanical pushes and pulls. But gravity did not seem 'mechanical', for its was action at a distance. For that very reason, Newton's only peer, Leibniz, quite rejected Newtonian gravitation: it was a reactionary reversion to inexplicable occult powers. A positivist spirit triumphed over Leibniz. We learned to think that the laws of gravity are regularities that describe what happens in the world. Then we decided that all causal laws are mere regularities!

For empirically minded people the post-Newtonian attitude was, then, this: we should not seek for causes in nature, but only regularities. We should not think of laws of nature revealing what must happen in the universe, but only what does happen. The natural scientist tries to find universal statements – theories and laws – which cover all phenomena as special cases. To say that we have found the explanation of an event is only to say that the event can be deduced from a general regularity.

There are many classic statements of this idea. Here is one from Thomas Reid's *Essays on the Active Powers of the Human Mind* of 1788. Reid was the founder of what is often called the Scottish School of Common Sense Philosophy, which was imported to form the main American philosophy until the advent of pragmatism at the end of the nineteenth century.

Natural philosophers, who think accurately, have a precise meaning to the terms they use in the science; and, when they pretend to show the cause of any phenomenon of nature, they mean by the cause, a law of nature of which that phenomenon is a necessary consequence.

The whole object of natural philosophy, as Newton expressly teaches, is reducible to these two heads: first, by just induction from experiment and observation, to discover the laws of nature; and then to apply those laws to the solution of the phenomena of nature. This was all that this great philosopher attempted, and all that he thought attainable. (I. vii. 6.)

Comte tells a similar story in his *Cours de philosophie positive*:

The first characteristic of the positive philosophy is that it regards all phenomena as subjected to invariable natural laws. Our business is – seeing how vain is any research into what are called causes, whether first or final – to pursue an accurate discovery of these laws, with a view to reducing them to the smallest possible number. By speculating upon causes, we could solve no difficulty about origin and purpose. Our real business is to analyze accurately the circumstances of phenomena, and to connect them by the natural relations of succession and resemblance. The best illustration of this is in the case of the doctrine of gravitation. We say that the general phenomena of the universe are explained by it, because it connects under one head the whole immense variety of astronomical facts; exhibiting the constant tendency of atoms towards each other in direct proportion to their masses, and in inverse proportion to the squares of their distances; while the general fact itself is a mere extension of one that is perfectly familiar to us and that we therefore say that we know – the weight of bodies on the surface of the earth. As to what weight and attraction are, these are questions that we regard as insoluble, which are not part of positive philosophy and which we rightly abandon to the imagination of the theologians or the subtlety of the metaphysicians. (Paris, 1830, pp. 14–16.)

Logical positivism was also to accept Hume's constant conjunction account of causes. Laws of Nature, in Mortitz Schlick's maxim, *describe* what happens, but do not *prescribe* it. They are accounts of regularities only. The logical positivist account of explanation was finally summed up in C.G. Hempel's 'deductive-nomological' model of explanation. To explain an event whose occurrence is described by the sentence *S* is to present some laws of nature (i.e. regularities) *L*, and some particular facts *F* and to show that the sentence *S* is deducible from sentences stating *L* and *F*. Van Fraassen, who has an interestingly more sophisticated account of explanation, shares the traditional positivist hostility to causes. 'Flights of fancy' he dismissively calls them in his book (for causes are even worse, in his book, than explanation).

#### Anti-theoretical-entities

Opposition to unobservable entities goes hand in hand with an opposition to causes. Hume's scorn for the entity-postulating sciences of his day is, as always, stated in an ironic prose. He admires the seventeenth-century chemist Robert Boyle for his experiments and his reasoning, but not for his corpuscular and mechanical philosophy that imagines the world to be made up of little bouncy balls or springlike tops. In Chapter LXII of his great *History of England* he tells us that, 'Boyle was a great partisan of the mechanical philosophy, a theory which, by discovering some of the secrets of nature and allowing us to imagine the rest, is so agreeable to the natural vanity and curiosity of men.' Isaac Newton, 'the greatest and rarest genius that ever arose for the ornament and instruction of the species', is a better master than Boyle: 'While Newton seemed to draw off the veil from some of the mysteries of nature, he showed at the same time the imperfections of the mechanical philosophy, and thereby restored her ultimate secrets to that obscurity in which they ever did and ever will remain.'

Hume seldom denies that the world is run by hidden and secret causes. He denies that they are any of our business. The natural vanity and curiosity of our species may let us seek fundamental particles, but physics will not succeed. Fundamental causes ever did and ever will remain cloaked in obscurity.

Opposition to theoretical entities runs through all positivism. Comte admitted that we cannot merely generalize from observations, but must proceed through hypotheses. These must, how-

ever, be regarded only as hypotheses, and the more that they postulate, the further they are from positive science. In practical terms, Comte was opposed to the Newtonian aether, soon to be electromagnetic aether, filling all space. He was equally opposed to the atomic hypothesis. You win one, you lose one.

The logical positivists distrusted theoretical entities in varying degrees. The general strategy was to employ logic and language. They took a leaf from Bertrand Russell's notebook. Russell thought that whenever possible, inferred entities should be replaced by logical constructions. That is, a statement involving an entity whose existence is merely inferred from data is to be replaced by a logically equivalent statement about the data. In general these data are closely connected with observation. Thereby arose a great programme of reductionism for the logical positivists, who hoped that all statements involving theoretical entities would by means of logic be 'reduced' to statements that did not make reference to such entities. The failure of this project was greater even than the failure to state the verification principle.

Van Fraassen continues the positivist antipathy to theoretical entities. Indeed he will not even let us speak of theoretical entities: we mean, he writes, simply unobservable entities. These, not being seen, must be inferred. It is van Fraassen's strategy to block every inference to the truth of our theories or the existence of their entities.

#### Believing

Hume did not believe in the invisible bouncy balls or atoms of Robert Boyle's mechanical philosophy. Newton had showed us that we ought only to seek natural laws that connect the phenomena. We should not allow our natural vanity to imagine that we can successfully seek out causes.

Comte equally disbelieved in the atoms and aether of the science of his time. We need to make hypotheses in order to tell us where to investigate nature, but positive knowledge must lie at the level of the phenomena whose laws we may determine with precision. This is not to say that Comte was ignorant of science. He was trained by the great French theoretical physicists and applied mathematicians. He believed in their laws of phenomena and distrusted any drive towards postulating new entities.

Logical positivism had no such simplistic opportunities.

Members of the Vienna Circle believed the physics of their day: some had made contributions to it. Atomism and electromagnetism had long been established, relativity was a proven success and the quantum theories were advancing by leaps and bounds. Hence arose, in the extreme version of logical positivism, a doctrine of reductionism. It was proposed that in principle there are logical and linguistic transformations in the sentences of theories that will reduce them to sentences about phenomena. Perhaps when we speak of atoms and currents and electric charges we are not to be understood quite literally, for the sentences we use are reducible to sentences about phenomena. Logicians did to some extent oblige. F.P. Ramsey showed how to leave out the names of theoretical entities in the theories, using instead a system of quantifiers. William Craig proved that for any axiomatizable theory involving both observational and theoretical terms, there exists an axiomatizable theory involving only the observational terms. But these results did not do quite what logical positivism wanted, nor was there any linguistic reduction for any genuine science. This was in terrible contrast to the remarkable partial successes by which more superficial scientific theories have been reduced to deeper ones, for example, the ways in which analytic chemistry is founded upon quantum chemistry, or the theory of the gene has been transformed into molecular biology. Attempts at scientific reduction – reducing one empirical theory to a deeper one – have scored innumerable partial successes, but attempts at linguistic reduction have got nowhere.

### Accepting

Hume and Comte took all that stuff about fundamental particles and said: We don't believe it. Logical positivism believed it, but said in a sense that it must not be taken literally; our theories are really talking about phenomena. Neither option is open to a present-day positivist, for the programmes of linguistic reduction failed, while on the other hand one can hardly reject the whole body of modern theoretical science. Yet van Fraassen finds a way through this impasse by distinguishing belief from acceptance.

Against the logical positivists, van Fraassen says that theories are to be taken literally. There is no other way to take them! Against the realist he says that we need not believe theories to be true. He invites us instead to use two further concepts: *acceptance* and *empirical*

*adequacy*. He defines scientific realism as the philosophy that maintains that, 'Science aims to give us, in its theories, a literally true story of what the world is like; and acceptance of a scientific theory involves the belief that it is true' (p. 8). His own *constructive empiricism* asserts instead that, 'Science aims to give us theories which are empirically adequate; and acceptance of a theory involves as belief only that it is empirically adequate' (p. 12).

'There is,' he writes, 'no need to believe good theories to be true, nor to believe *ipso facto* that the entities they postulate are real.' The '*ipso facto*' reminds us that van Fraassen does not much distinguish realism about theories from realism about entities. I say that one could believe entities to be real, not 'in virtue of the fact' that one believes some theory to be true, but for other reasons.

A little later van Fraassen explains as follows: 'to accept a theory is (for us) to believe that it is empirically adequate – that what the theory says *about what is observable* (by us) is true' (p. 18). Theories are intellectual instruments for prediction, control, research and sheer enjoyment. Acceptance means commitment, among other things. To accept a theory in your field of research is to be committed to developing the programme of inquiry that it suggests. You may even accept that it provides explanations. But you must reject what has been called inference to the best explanation: to accept a theory because it makes something plain is not thereby to think that what the theory says is literally true.

Van Fraassen's is the most coherent present-day positivism. It has all six features by which I define positivism, and which are shared by Hume, Comte and the logical positivists. Naturally it lacks Hume's psychology, Comte's historicism, and logical positivism's theories of meaning, for those have nothing essential to do with the positivist spirit. Van Fraassen shares with his predecessors the *anti-metaphysics*: 'The assertion of empirical adequacy is a great deal weaker than the assertion of truth, and the restraint to acceptance delivers us from metaphysics' (p. 69). He is *pro-observation*, and *anti-cause*. He *downplays explanation*; he does not think explanation leads to truth. Indeed, just like Hume and Comte, he cites the classic case of Newton's inability to explain gravity as proof that science is not essentially a matter of explanation (p. 94). Certainly he is *anti-theoretical-entities*. So he holds five of our six positivist doctrines. The only one left is the emphasis



on *verification* or some variant. Van Fraassen does not subscribe to the logical positivist verifiability theory of meaning. Nor did Comte. Nor, I think, did Hume, although Hume did have an unverifiability maxim for burning books. The positivist enthusiasm for verifiability was only temporarily connected with meaning, in the days of logical positivism. More generally it represents a desire for positive science, for knowledge that can be settled as true, and whose facts are determined with precision. Van Fraassen's constructive empiricism shares this enthusiasm.

### Anti-explanation

Many positivist theses were more attractive in Comte's day than our own. In 1840, theoretical entities were thoroughly hypothetical, and distaste for the merely postulated is the starting point for some sound philosophy. But increasingly we have come even to see what was once merely postulated: microbes, genes, even molecules. We have also learned how to use many theoretical entities in order to manipulate other parts of the world. These grounds for realism about entities are discussed in Chapters 10 and 16 below. However one positivist theme stands up rather well: caution about explanation.

The idea of 'inference to the best explanation' is quite old. C.S. Peirce (1839-1914) called it the method of hypothesis, or abduction. The idea is that if, confronted by some phenomenon, you find one explanation (perhaps with some initial plausibility) that makes sense of what is otherwise inexplicable, then you should conclude that the explanation is probably right. At the start of his career Peirce thought that there are three fundamental modes of scientific inference: deduction, induction and hypothesis. The older he got the more sceptical he became of the third category, and by the end of his life he attached no weight at all to 'inference to the best explanation'.

Was Peirce right to recant so thoroughly? I think so, but we need not decide that now. We are concerned only with inference to the best explanation as an argument for realism. The basic idea was enunciated by H. Helmholtz (1821-94), the great nineteenth-century contributor to physiology, optics, electrodynamics and other sciences. Helmholtz was also a philosopher who called realism

'an admirably useful and precise hypothesis'.<sup>1</sup> By now there appear to be three distinct arguments in circulation. I shall call them the simple inference argument, the cosmic accident argument, and the success of science argument.

I am sceptical of all three. I should begin by saying that explanation may play a less central a role in scientific reasoning than some philosophers imagine. Nor is *the* explanation of a phenomenon one of the ingredients of the universe, as if the Author of Nature had written down various things in the Book of the World – the entities, the phenomena, the quantities, the qualities, the laws, the numerical constants, and also the explanations of events. Explanations are relative to human interests. I do not deny that explaining – 'feeling the key turn in the lock' as Peirce put it – does happen in our intellectual life. But that is largely a feature of the historical or psychological circumstances of a moment. There are times when we feel a great gain in understanding by the organization of new explanatory hypotheses. But that feeling is not a ground for supposing that the hypothesis is true. Van Fraassen and Cartwright urge that being an explanation is never a ground for belief. I am less stringent than they: it seems to me like Peirce to be merely a feeble ground. In 1905 Einstein explained the photoelectric effect with a theory of photons. He thereby made attractive the notion of quantized bundles of light. But the ground for believing the theory is its predictive success, and so forth, not its explanatory power. Feeling the key turn in the lock makes you feel that you have an exciting new idea to work with. It is not a ground for the truth of the idea: that comes later.

### Simple inference

The simple inference argument says it would be an absolute miracle if for example the photoelectric effect went on working while there were no photons. The explanation of the persistence of this phenomenon – the one by which television information is converted from pictures into electrical impulses to be turned into electromagnetic waves in turn to be picked up on the home receiver – is

<sup>1</sup> 'On the aim and progress of physical science' (German original 1871) in H. von Helmholtz, *Popular Lectures and Addresses on Scientific Subjects* (D. Atkinson trans.), London, 1873, p. 247.

that photons do exist. As J.J.C. Smart expresses the idea: 'One would have to suppose that there were innumerable lucky accidents about the behavior mentioned in the observational vocabulary, so that they behaved miraculously *as if* they were brought about by the non-existent things ostensibly talked about in the theoretical vocabulary.'<sup>2</sup> The realist then infers that photons are real because otherwise we could not understand how scenes are turned into electronic messages.

Even if, contrary to what I have said, explanation were a ground for belief, this seems not to be an inference to the best explanation at all. That is because the *reality* of photons is no part of the explanation. There is not, after Einstein, some further explanation, namely 'and photons are real', or 'there exist photons'. I am inclined to echo Kant, and say that existence is a merely logical predicate that adds nothing to the subject. To add 'and photons are real', after Einstein has finished, is to add nothing to the understanding. It is not in any way to increase or enhance the explanation.

If the explainer protests, saying that Einstein himself asserted the existence of photons, then he is begging the question. For the debate between realist and anti-realist is whether the adequacy of Einstein's theory of the photon does require that photons be real.

### Cosmic accidents

The simple inference argument considers just one theory, one phenomenon and one kind of entity. The cosmic accident argument notes that often in the growth of knowledge a good theory will explain diverse phenomena which had not hitherto been thought of as connected. Conversely, we often come at the same brute entities by quite different modes of reasoning. Hans Reichenbach called this the common cause argument, and it has been revived by Wesley Salmon.<sup>3</sup> His favoured example is not the photoelectric effect but another of Einstein's triumphs. In 1905 Einstein also explained the Brownian movement – the way in which, as we now say, pollen particles are bounced around in a random way by being hit by molecules in motion. When Einstein's calculations are combined

2 J.J.C. Smart, 'Difficulties for realism in the philosophy of science', in *Logic, Methodology and Philosophy of Science VI*, Proceedings of the 6th International Congress of Logic, Methodology and Philosophy of Science, Hannover, 1979, pp. 363–75.

3 Wesley Salmon, 'Why ask, "Why?" An Inquiry Concerning Scientific Explanation', *Proceedings and Addresses of the American Philosophical Association* 51 (1978), pp. 683–705.

with the results of careful experimenters, we are able, for example, to compute Avogadro's number, the number of molecules of an arbitrary gas contained in a given volume at a set temperature and pressure. This number had been computed from numerous quite different sources ever since 1815. What is remarkable is that we always get essentially the same number, coming at it from different routes. The only explanation must be that there *are* molecules, indeed, some  $6.023 \times 10^{23}$  molecules per gram-mole of any gas.

Once again, this seems to me to beg that realist/anti-realist issue. The anti-realist agrees that the account, due to Einstein and others, of the mean free path of molecules is a triumph. It is empirically adequate – wonderfully so. The realist asks why is it empirically adequate – is that not because there just are molecules? The anti-realist retorts that explanation is no hall-mark of truth, and that all our evidence points only to empirical adequacy. In short the argument goes around in circles (as, I contend, do all arguments conducted at this level of discussion of theories).

### The success story

The previous considerations bear more on the existence of entities; now we consider the truth of theories. We reflect not on one bit of science but on 'Science' which, Hilary Putnam tells us, is a Success. This is connected with the claim that Science is converging on the truth, as urged by many, including W. Newton-Smith in his book *Rationality* (1982). Why is Science Successful? It must be because we are converging on the truth. This issue has now been well aired, and I refer you to a number of recent discussions.<sup>4</sup> The claim that here we have an 'argument' drives me to the following additional expostulations:

1 The phenomenon of growth is at most a monotonic increase in knowledge, not convergence. This trivial observation is important, for 'convergence' implies somewhat that there is *one* thing being converged on, but 'increase' has no such implication. There can be heapings up of knowledge without there being any unity of

4 Among many arguments in favour of this idea of convergence, see R.N. Boyd, 'Scientific realism and naturalistic epistemology', in P.D. Asquith and R. Giere (eds.), *PSA 1980*, Volume 2, Philosophy of Science Assn., East Lansing, Mich., pp. 613–62, and W.H. Newton-Smith, *The Rationality of Science*, London, 1981. For a very powerful statement of the opposite point of view, see L. Laudan, 'A confutation of convergent realism', *Philosophy of Science* 48 (1981), pp. 19–49.

science to which they all add up. There can also be an increasing depth of understanding, and breadth of generalization, without anything properly called convergence. Twentieth-century physics is a witness to this.

2 There are numerous merely sociological explanations of the growth of knowledge, free of realist implications. Some of these deliberately turn the 'growth of knowledge' into a pretence. On Kuhn's analysis in *Structure*, when normal science is ticking over nicely, it is solving the puzzles that it creates as solvable, and so growth is built in. After revolutionary transition, the histories are rewritten so that early successes are sometimes ignored as uninteresting, while the 'interesting' is precisely what the post-cataclysmic science is good at. So the miraculously uniform growth is an artifact of instruction and textbooks.

3 What grows is not particularly the strictly increasing body of (nearly true) *theory*. Theory-minded philosophers fixate on accumulation of theoretical knowledge – a highly dubious claim. Several things do accumulate. (a) Phenomena accumulate. For example, Willis Lamb is trying to do optics without photons. Lamb may kill off the photons but the photoelectric effect will still be there. (b) Manipulative and technological skills accumulate – the photoelectric effect will still be opening the doors of supermarkets. (c) More interestingly to the philosopher, styles of scientific reasoning tend to accumulate. We have gradually accumulated a horde of methods, including the geometrical, the postulational, the model-building, the statistical, the hypothetico-deductive, the genetic, the evolutionary, and perhaps even the historicist. Certainly there is growth of types (a), (b), and (c), but in none of them is there any implication about the reality of theoretical entities or the truth of theories.

4 Perhaps there is a good idea, which I attribute to Imre Lakatos, and which is foreshadowed by Peirce and the pragmatism soon to be described. It is a route open to the post-Kantian, post-Hegelian, who has abandoned a correspondence theory of truth. One takes the growth of knowledge to be a given fact, and tries to characterize truth in terms of it. This is not explanation by assuming a reality, but a definition of reality as 'what we grow to'. That may be a mistake, but at least it has an initial cogency. I describe it in Chapter 8 below.

5 Moreover, there are genuine conjectural inferences to be drawn from the growth of knowledge. To cite Peirce again, our talents at forming roughly the right expectations about the human-sized world may be accounted for by the theory of evolution. If we regularly formed the wrong expectations, we would all be dead. But we seem to have an uncanny ability to formulate structures that explain and predict both the inner constitution of nature, and the most distant realms of cosmology. What can it have benefited us, in terms of survival, that we have a brain so toolled for the lesser and the larger universe? Perhaps we should guess that people are indeed rational animals that live in a rational universe. Peirce made a more instructive if implausible proposal. He asserted that strict materialism and necessitarianism are false. The whole world is what he called 'effete mind', which is forming habits. The habits of inference that we form about the world are formed according to the same habits that the world used as it acquired its increased spectrum of regularities. That is a bizarre and fascinating metaphysical conjecture that might be turned into an explanation of 'the success of science'.

How Peirce's imagination contrasts with the banal emptiness of the Success Story or convergence argument for realism! Popper, I think, is a wiser self-professed realist than most when he writes that it never makes sense to ask for the explanation of our success. We can only have the faith to hope that it will continue. If you must have an explanation of the success of science, then say what Aristotle did, that we are rational animals that live in a rational universe.