CHAPTER I

SCIENTIFIC EPISTEMOLOGY

I

BETWEEN physics and philosophy there lies a debatable territory which I shall call *scientific epistemology*. Epistemology is that branch of philosophy which treats of the nature of knowledge. It will not be denied that a significant part of the whole field of knowledge is that which has come to us by the methods of physical science. This part takes the form of a detailed description of a world—the so-called physical universe. I give the name "scientific epistemology" to the sub-branch of epistemology which deals with the nature of this part of our knowledge, and therefore indirectly with the nature and status of the physical universe to which it formally relates.

There are two matters of definition which it is desirable to make clear at the outset.

Some writers restrict the term "knowledge" to things of which we are quite certain; others recognise knowledge of varying degrees of uncertainty. This is one of the common ambiguities of speech as to which no one is entitled to dictate, and an author can only state which usage he has himself chosen to follow. If "to know" means "to be quite certain of", the term is of little use to those who wish to be undogmatic. I therefore prefer the broader meaning; and my own usage will recognise uncertain knowledge. Anything which would be knowledge if we were assured of its truth, is still counted as knowledge (uncertain or false knowledge) if we are not assured.

It will not be necessary for us to formulate a general definition of knowledge. Our procedure will be to specify

a particular collection of more or less widely accepted knowledge, and then to make an epistemological study of its nature. Especially, though not exclusively, we have to consider the knowledge acquired by the methods of physical science. For brevity I will call this *physical knowledge*. In principle we might identify physical knowledge with the contents of certain encyclopaedic works, such as the *Handbuch der Physik*, which between them cover the various branches of physical science. But there are obvious objections to a slavish acceptance of a particular authority; and I will therefore define physical knowledge to be that which a right-thinking person* would to-day accept as justified by physical science.

It should not be overlooked that physical knowledge includes a vast amount of miscellaneous information which would be out of place in scientific text-books. For example, the result of a measurement of weight is physical knowledge, whether it is made for the purpose of deciding a scientific issue or for deciding the amount of a tradesman's bill. The condition is that it shall be passed as scientifically correct (by the right-thinking person), not that it shall be scientifically important. It should also be noticed that the term is intended to refer to physical science as it stands to-day. We are not going to occupy ourselves with speculations as to possible future developments. We are to take stock of the results which the methods of physical science have yielded up to now, and see what kind of knowledge we have been acquiring.

I have said that I do not regard the term "knowledge" as implying assurance of truth. But in considering a particular body of knowledge, it may be assumed that an effort has been made to admit to that body only the more trustworthy knowledge; so that usually a reasonable degree of certainty

* "Right-thinking person" is, of course, a modest way of referring to oneself.

or probability is attributable to the knowledge which we shall have occasion to discuss. But the assessment of certainty of knowledge is to be regarded as separate from the study of the nature of knowledge.

The other matter of definition is the term "physical universe". Physical knowledge (as accepted and formulated to-day) has the form of a description of a world. We *define* the physical universe to be the world so described. Effectively therefore the physical universe is defined as the theme of a specified body of knowledge, just as Mr Pickwick might be defined as the hero of a specified novel.

A great advantage of this definition is that it does not prejudge the question whether the physical universe—or Mr Pickwick—really exists. That is left open for discussion if we can agree on a definition of "really exists", which for most persons is a parrot-phrase whose meaning they have not troubled to consider. The few who have attempted to give it a definite meaning do not always agree on the meaning. By defining the physical universe and the physical objects which constitute it as the theme of a specified body of knowledge, and not as things possessing a property of existence elusive of definition, we free the foundations of physics from suspicion of metaphysical contamination.

This type of definition is characteristic of the epistemological approach, which takes knowledge as the starting point rather than an existent entity of which we have somehow to obtain knowledge. But in defining scientifically a term already in common use, we must be careful to avoid abuse of language. To justify the above definition of the physical universe, we ought to show that it is not in conflict with what the ordinary man (in which term I do not include philosophers) understands by the physical universe. This justification is deferred to p. 159.

II

The nature of physical knowledge and of the world which it professes to describe has long been a battleground for rival schools of philosophers. But physicists can scarcely be denied a hearing on a subject which concerns them so intimately. A student of physical science should be in a position to throw some light on the nature of the knowledge obtainable by the methods which he practises. Recently a number of books have been written by authors whose qualifications are purely scientific, in which scientific epistemology is developed and used as an approach to the wider problems of philosophy. I do not think that this "intrusion" into philosophy is a matter for surprise or caustic comment.

One often finds an impression that it is an innovation for scientists to indulge in philosophy; but this is incorrect. I have noticed that some of the recent books are plentifully sprinkled with quotations from scientists of the nineteenth century which, whether they fortify the argument or not, prove at any rate that our predecessors shared the common foible of holding strong philosophic views—and expressing them. Some were out of their depth, then as now. But some were profound thinkers—Clifford, Karl Pearson, Poincaré, and others—whose writings have an honoured place in the development of scientific philosophy.

It is, however, important to recognise that about twenty-five years ago the invasion of philosophy by physics assumed a different character. Up till then traffic with philosophy had been a luxury for those scientists whose disposition happened to turn that way. I can find no indication that the scientific researches of Pearson and Poincaré were in any way inspired or guided by their particular philosophical outlook. They had no opportunity to put their philosophy into practice. Conversely, their philosophical conclusions were

the outcome of general scientific training, and were not to any extent dependent on familiarity with recondite investigations and theories. To advance science and to philosophise on science were essentially distinct activities. In the new movement scientific epistemology is much more intimately associated with science. For developing the modern theories of matter and radiation a definite epistemological outlook has become a necessity; and it is the direct source of the most far-reaching scientific advances.

We have discovered that *it is actually an aid in the search for knowledge to understand the nature of the knowledge which we seek*.

By making practical application of our epistemological conclusions we subject them to the same kind of observational control as physical hypotheses. If our epistemology is at fault, it will lead to an *impasse* in the scientific developments proceeding from it; that warns us that our philosophical insight has not been deep enough, and we must cast about to find what has been overlooked. In this way scientific advances which result from epistemological insight have in turn educated our epistemological insight. Between science and scientific epistemology there has been a give and take by which both have greatly benefited.

In the view of scientists at least, this observational control gives to modern scientific epistemology a security which philosophy has not usually been able to attain. It introduces also the same kind of progressive development which is characteristic of science, but not hitherto of philosophy. We are not making a series of shots at ultimate truth, which may hit or miss. What we claim for the present system of scientific philosophy is that it is an advance on that which went before, and that it is a foundation for the advances which will come after it.

In science the observational test is valuable, not only for controlling physical hypotheses (for which it is indeed the

only possible guarantee), but also for detecting fallacies of argument and unwarranted assumptions. It is the latter kind of control that an observational test applies to scientific epistemology. This may seem superfluous to those who never reason incorrectly. But perhaps even the most confident philosopher will admit that there are some of his opponents to whom such control would be salutary. I have little doubt that every one of the philosophical conclusions in this book has been anticipated by one of the schools of philosophy—and emphatically condemned by another. But to those who recognise them as familiar truisms or as long-condemned fallacies, I would point out that they are now put forward with altogether new sanctions which ought to be reckoned with.

Theoretical physicists, through the inescapable demands of their own subject, have been forced to become epistemologists, just as pure mathematicians have been forced to become logicians. The invasion of the epistemological branch of philosophy by physics is exactly parallel to the invasion of the logical branch of philosophy by mathematics. Pure mathematicians, having learnt by experience that the obvious is difficult to prove—and not always true—found it necessary to delve into the foundations of their own processes of reasoning; in so doing they developed a powerful technique which has been welcomed for the advancement of logic generally. A similar pressure of necessity has caused physicists to enter into epistemology, rather against their will. Most of us, as plain men of science, begin with an aversion to the philosophic type of inquiry into the nature of things. Whether we are persuaded that the nature of physical objects is obvious to commonsense, or whether we are persuaded that it is inscrutable beyond human understanding, we are inclined to dismiss the inquiry as unpractical and futile. But modern physics has not been able to maintain this aloofness. There can be little doubt that its advances, though applying

primarily to the restricted field of scientific epistemology, have a wider bearing, and offer an effective contribution to the philosophical outlook as a whole.

Formally we may still recognise a distinction between science, as treating the *content* of knowledge, and scientific epistemology, as treating the *nature* of knowledge of the physical universe. But it is no longer a practical partition; and to conform to the present situation scientific epistemology should be included in science. We do not dispute that it must also be included in philosophy. It is a field in which philosophy and physics overlap.

III

So long as a scientific writer on philosophy confines himself to scientific epistemology, he is not outside the borders of his own subject. But most authors have felt that they could usefully advance farther and consider the general philosophical bearing of the new conceptions. This venturesomeness has been strongly criticised; but it seems to me that the critics have failed to grasp the situation.

It is recorded that Archbishop Davidson, in conversation with Einstein, asked him what effect he thought the theory of relativity would have on religion. Einstein answered: "None. Relativity is a purely scientific theory, and has nothing to do with religion." In those days one had to become expert in dodging persons who were persuaded that the fourth dimension was the door to spiritualism, and the hasty evasion is not surprising. But those who quote and applaud the remark as though it were one of Einstein's most memorable utterances overlook a glaring fallacy in it. Natural selection is a purely scientific theory. If in the early days of Darwinism the then Archbishop had asked what effect the theory of natural selection would have on religion, ought the answer to have been "None. The Darwinian

theory is a purely scientific theory, and has nothing to do with religion"?

The compartments into which human thought is divided are not so water-tight that fundamental progress in one is a matter of indifference to the rest. The great change in theoretical physics which began in the early years of the present century is a purely scientific development; but it must affect the general current of human thought, as at earlier times the Copernican and the Newtonian systems have done. This alone would seem to justify the scientific authors in taking a broad view of their task. It seems to me unreasonable to maintain that the working out of these wider implications of the new conception of the physical universe should be left entirely to those who do not understand it.

Not so very long ago the subject now called physics was known as "natural philosophy". The physicist is by origin a philosopher who has specialised in a particular direction. But he is not the only victim of specialisation. By the breaking away of physics the main body of philosophy suffered an amputation. In practice, if not in theory, academic philosophy has also become specialised, and is no longer coextensive with the system of thought and knowledge by which we orient ourselves towards our moral and material environment. To a man's philosophy in the broadest sense—to his *religio vitae*—natural philosophy, under the name of science, has continued to be a powerful, perhaps even a predominant, contributor. It would be difficult to point to any development in academic philosophy which has had so great an influence on man's outlook as the growth of the scientific theory of evolution. In the last twenty years it has been the turn of physics to reassert itself as natural philosophy; and I believe that the new contribution of physical science, if fully grasped, is not less significant than the doctrine of evolution.

We may define rather more closely the status of a scientist

who writes on the philosophical outcome of modern physical theories. I do not think that any school of philosophers is prepared to wash its hands of the physical universe and leave the physicists to make what they like of it. It seems therefore to be agreed that scientific epistemology is still an integral part of philosophy. Those whose work lies in the epistemological developments of modern physics must therefore be counted as specialists in one of the departments into which philosophy is divided—a department not far from the heart of the subject. In their discussion of philosophy as a whole they are likely to display the faults of a specialist who finds himself outside his own groove; but they are not common intruders. The evils of specialisation would, I think, be still more pronounced if they made no attempt to correlate with the rest of philosophy the progress that has been made in their own department.

Scientific epistemology is the main theme of these lectures. We shall consider it primarily from the scientific aspect. But we shall also at times endeavour to view it in its general setting as a region of overlap of physics and philosophy, and trace its consequences in both fields.

IV

For the truth of the conclusions of physical science, observation is the supreme Court of Appeal. It does not follow that every item which we confidently accept as physical knowledge has actually been certified by the Court; our confidence is that it would be certified by the Court if it were submitted. But it does follow that every item of physical knowledge is of a form which might be submitted to the Court. It must be such that we can specify (although it may be impracticable to carry out) an observational procedure which would decide whether it is true or not. Clearly a statement cannot be tested by observation unless it is an

assertion about the results of observation. *Every item of physical knowledge must therefore be an assertion of what has been or would be the result of carrying out a specified observational procedure.*

I do not think that anyone—least of all, those who are critical of the modern tendencies of physics—will disagree with the first axiom of scientific epistemology, namely that the knowledge obtained by the methods of physical science is limited to observational knowledge in the sense explained above. We do not deny that knowledge which is not of an observational nature may exist, e.g. the theory of numbers in pure mathematics; and non-committally we may allow the possibility of other forms of insight of the human mind into a world outside itself. But such knowledge is beyond the borders of physical science, and therefore does not enter into the description of the world introduced in the formulation of physical knowledge. To a wider synthesis of knowledge, of which physical knowledge is only a part, we may perhaps correlate a "world" of which the physical universe is only a partial aspect. But at this stage of our inquiry we limit the discussion to physical knowledge, and therefore to a physical universe from which, by definition, all characteristics which are not the subject of physical knowledge are excluded.

A distinction is commonly made between observational and theoretical knowledge; but in practice the terms are used so loosely as to deprive the classification of all real significance. The whole development of physical science has been a process of combining theory and observation; and in general every item of physical knowledge—or at least every item to which attention is ordinarily directed—has a partly observational and partly theoretical basis. The distinction, so far as it can be made, has reference to the mode of obtaining the knowledge—to the nature of the evidence for its truth. It does not concern the knowledge itself—what it is we intend to assert. Thus our axiom that all