THE NATURE OF SCIENCE*

By H. H. PLASKETT

THE failure of thoughtful people more widely to adopt the descriptive view of science shows to some extent that its simplicity and important implications have not been completely understood. And yet this view, if for no other reason than that it was originated by such masters as Kirchhoff, Mach and Poincaré, is worthy of the attention of all students of science. There is then, perhaps, room for an article which will give a concise account of this view and serve as an introduction to Hobson's authoritative *Gifford Lectures* or Pearson's *Grammar of Science*. The present article represents an imperfect attempt to meet this need; the descriptive view of science is here discussed under the headings of facts and their classification, laws and theories and finally the relation of science to philosophy.

1. *The Facts of Science and their Classification*

Facts form the subject matter of science. A distinction must, however, be recognized between the primitive facts which result from our sense impressions and those facts, ordinarily obtained in science to-day, whose very existence depends upon a number of accepted theories and laws. Even so simple an operation as the measurement of a length involves the pre-existence of some system of geometry, while the determination of a stellar position can be shown to depend upon at least a dozen scientific laws. In their origin, however, these facts, now a consequence of laws, were none other than primitive facts dependent upon sense data; a discussion of these sense data should then reveal the essential nature of the facts of science.

Before me, as I write, there is a table. From the table I receive and recall by memory certain sense data of colour, smoothness,

*From a lecture before the Victoria Centre of the Royal Astronomical Society of Canada.

shape, hardness and sound when it is rapped. While generally I may describe the table as brown, it must be admitted that the colour varies as I move about the room and also depends upon the quantity of light falling on the table. Again, while the table appears smooth to my unaided eye, with a microscope it would appear rough and uneven; similarly the shape varies with my position, and the hardness depends upon how strongly and with what part of my body I press upon the table. Indeed I would find it difficult to state what the "real" colour, smoothness, shape and hardness of the table are, although I can describe the apparent table so that it is immediately recognizable to anyone else. The *apparent* table depends upon us, its observers, and we do not seem able to disentangle the *real* table from our sense data. Indeed the real existence of the table apart from us who observe it, may be and has been doubted; its actual nature, if it does exist, is not and perhaps never will be known. But though the real table is not known, the existence of the sense data, on the other hand, cannot be questioned. Science, on the descriptive view, is therefore content to take as the fact, that which cannot be doubted, the sense data. The table is thus, for science only a construct made up of immediate and recalled sense data. There may be some "thing in itself" which gives rise to these sense data, but this strange thing which we can know only imperfectly, if at all, is not the fact for science; that fact is simply the sum of the sense data.

Science imposes two limitations on the facts which it discusses, the limitation of universal assent and of frequent repetition. In the first place the facts or perceptions discussed must be only those to which everyone agrees; an experiment or an observation, to form part of the subject matter of science, must be reproducible by any worker. The relative backwardness of psychical research, in spite of forty years work by the great English society, may be attributed with some certainty to a subject matter made up of facts to which not every one assents. In the second place the facts to be discussed must be common; they must frequently thrust themselves upon our attention. If, as Poincaré has supposed, there had been 10^9 equally abundant elements in place of 88, so that every pebble we picked up had been a different element, then the science of chemistry would not have been possible. This second limitation, however, only operates at the initiation of a science; once the science is established the subject matter is by no means limited to common facts, but is extended to include peculiar and infrequent events.

Facts, which are simply sense data and which are subject to the limitations just described, form the subject matter of science. The first step in their use is an apportionment of these facts to various branches of science. Thus botany treats of facts relating to plant life, astronomy of observations of the heavenly bodies, mineralogy of the components of the earth's crust, and so on. This apportionment is an approximate application of the method of classification, which may be defined as the grouping together of facts which have some property in common. Classification is not only used in the division of the subject matter amongst the various branches of science, but it is also historically the first method used in the sciences themselves. An example will make its nature clear. One of the earliest classifications of the stars was by their apparent brightness; in Ptolemy's catalogue all the stars visible to the unaided eye were grouped into six classes or magnitudes. This classification has been retained to the present day, in spite of the fact that stars of the same apparent magnitude may differ in distance, in motion, in temperature and in mass. In short when we speak of stars of the third magnitude, say, we *abstract* all those qualities in which the stars differ and consider the one property, apparent magnitude, which they have in common. A star of the third magnitude is a concept, which enables us to summarize a group of facts. Throughout this paper the word *concept* will be used to denote an abstract idea devised by the mind of man which may, or may not, correspond to some construct of sense data or percept in the external world. Classification is then the description of groups of facts by the aid of concepts, in which abstraction is made of the differences and the attention concentrated on the similarities common to the group. Classification is among the more powerful methods of science, and in some branches almost the only successful method used up to the present time.

2. *The Laws and Theories of Science*

Even the most casual examination of our experience reveals the association of certain facts; in some cases this association is so uniform as to give us a considerable power of prediction. When the sun sets at night we anticipate it will rise on the morrow, if we release an object we expect it to fall, if we omit our dinner we will be hungry, and so on. It is the association of facts, of which these are simple examples, that it is the fundamental business of science to study, and the results of this study are expressed in laws and theories.

An appreciation of the nature of laws and theories can be most conveniently reached from a consideration of the results in some branch of science; for this purpose optics is particularly suitable. Some of the phenomena in optics, such as the reflection of bushes and trees or the apparent bending of a stick in water, must have been familiar even to the most primitive people. By the time of Plato these facts had been so frequently studied that it was possible to state two definite relations. The first of these was that light travelled in straight lines. In this statement there are two concepts, a straight line, which is a well known abstract idea in Euclid, and light a concept devised for the purpose of optics. No one in fact has ever seen, or heard or felt light; it is a purely mental invention of Plato and his students. With the aid of these two concepts the relation describes in short hand form the phenomena of shadows and pin-hole images. The relation is a proto-type of the laws of science—a conceptual description of perceptual experience; it is not an objective law which Nature of necessity obeys; it is only a description of a strictly limited series of facts. The second of the relations stated by Plato was the equality of the angles of the incident and reflected beams—likewise a purely conceptual description of experience in which the concepts are geometrical. Though Ptolemy had drawn up tables of the angles of incident and refracted beams, neither he nor Kepler much later were able to summarize these facts in a single statement. It was left for Snell in the seventeenth century to discover the law of refraction, which again is none other than a simple conceptual description of experimental facts, though a description which must excite admiration for its deviser. By the aid of these three laws on the rectilinear propagation, reflection and refraction of light we are able to describe conceptually a large number of hitherto unrelated facts. But physicists were not satisfied and sought, in the language of the older view of science, a physical explanation of these laws. Two rival theories were proposed, one of which stated that light was composed of minute corpuscles travelling in straight lines, and the other that light was a wave motion in the ether. On the descriptive view of science we recognize that these theories are also simply conceptual relations, no different in character from the laws. The theories are merely wider in scope and are designed by the mind of man to summarize the laws and other facts, previously uncoordinated, in one comprehensive statement. In these theories the corpuscles and the ether are concepts, whose properties have been so postulated that an adequate description of the facts will result. While each of the theories is equally self consistent and the deductions alike logically necessary, the wave theory alone has survived, because with the minimum number of postulates, it has described a greater range of perceptual experience. Without further reference to optics we may conclude, on the view of science now being advanced, that laws and theories are simply conceptual descriptions of large numbers of facts. While in general a theory summarizes a greater body of facts than a law, the term applied to the descriptive formula is largely a matter of historical usage; thus the most remarkable theoretical generalization ever devised is called the law of gravitation.

This new descriptive view of science is characterized by two marked differences from the older view. One of these, already discussed, is that no assumption is now made as to the "real" nature of external objects which are regarded for the purposes of science only as constructs of present and past sense data. The other difference, which must here be stressed, is that the notions of efficient causation and necessity applied to external phenomena are also rejected. When I move a chair, or throw a ball, I regard myself as the cause of the resulting motion; such causation is termed efficient. This notion has been transferred to natural phenomena so that, when an event *A* invariably precedes an event *B*, *A* is regarded as the efficient cause of *B*—that is the occurrence of A is supposed to force the occurrence of B. This notion, which has played a very important part in the history of science, is implicit when we seek explanations; for example when we ask why does a body fall to the ground we are seeking an efficient cause. In the final analysis it must be admitted that all we do is describe how the body falls, we have never found why it falls. Again the notion of efficient causation is at the bottom of the distaste for action at a distance. Just as I, the efficient cause, have to be in contact with the chair before I can move it, so scientists, including Newton, have felt that there had to be interaction of some material bodies to explain the law of gravitation. While these various notions arising out of efficient causation may be perfectly valid, on the descriptive view they are no longer needed. Again it is logically necessary, according to the law of gravitation, that two mass points should revolve in elliptical orbits about their common centre of gravity, describing equal areas in equal times; but this necessity cannot be transferred from the conceptual theory to the natural phenomena. For there is no necessity that the earth should revolve about the sun in this manner, and no assurance, only a high degree of probability, that it will so continue to move to-morrow. In short, science is not concerned in the search for possible efficient causes or for necessity in Nature, but is content to describe conceptually what we observe.

A law or theory is "true" on the descriptive view of science when it is logically consistent, when it describes adequately the facts which it was designed to summarize, when it is simple and when it has a power of prediction. These four requirements may be considered in turn.

(1) Logical inconsistency may arise in framing the concepts and postulates of a theory; an example is the ordinary dynamical theory where, as Mach pointed out, force, work and kinetic energy are not independent concepts but are derived from the fundamental concepts of mass, space and time. Or logical inconsistency may arise in the development of a theory, where owing to mathematical difficulties, physicists err as to the deductions from the postulates. An example is the long controversy on the stability of the pear-shaped figure of equilibrium in the theory of a rotating incompressible fluid.

(2) A law or theory may be logically consistent and yet fail to describe the facts for whose description it was invented. On the caloric theory, heat was due to a universal, indestructible and uncreatable fluid which was also elastic and self-repellent; this fluid of course was simply a concept with certain postulated properties. Expansion of heated bodies was thus conceptually described by the self-repulsion of the caloric, specific heat by the varying attraction of different materials for the fluid and the heat developed by friction or percussion as caloric pounded or abraded out of the body. The theory failed, however, adequately to describe friction, in so far as Count Rumford showed that the heat there developed was inexhaustible. But caloric on its postulated properties was uncreatable and hence the theory, while still logically consistent, failed to describe one of the very facts it was designed to summarize.

(3) Successful theories tend to the greatest simplicity and abstraction. If a theory is devised with certain concepts which on account of metaphysical leanings, seem necessary to its creator, those concepts either prove the ultimate un-doing of the theory or are in the course of time eliminated. To the Greeks the fixity of the earth and motion in circular orbits were such necessary concepts. But the observed movements of the planets could not be described by simple circular orbits with the earth at the centre, and so it was necessary to postulate that the planet moved in an epicycle, or small circle, whose centre in turn travelled about a larger circle, or deferent, described about the earth as centre. We already note a considerable complication which with more refined observations had to be so greatly increased, that the Ptolemaic theory became un-usable. On the other hand the second law of thermodynamics, as first stated by Carnot, contained the concept of the caloric; this concept proved unnecessary to the law and has been omitted in all subsequent statements.

(4) The ultimate test of the validity of a theory lies in its power to predict phenomena outside the range of facts it was designed to describe. Newton's corpuscular theory of light furnishes a simple, logically consistent description of the observed phenomena of rectilinear propagation, reflection and refraction. It failed, however, to predict the retardation in light velocity in a dense

medium and the phenomena of interference and diffraction; it was accordingly superseded by the wave theory which did predict these facts. Again the great success of the quantum theory has been due to its applicability to the description of the photo-electric effect, the production of X-rays and the origin of line spectra, whereas it had its origin in an attempt to describe the phenomena in the very limited domain of heat radiation.

3. *The Relation of Science to Philosophy*

A satisfactory view of the purposes of science should not only provide an adequate account of the nature of scientific results, but should also be based on the minimum number of metaphysical postulates. For it is unfortunately true, as a result of the very nature of philosophical enquiry, that the results of such enquiry do not receive universal assent. In any attempt to determine the nature of existence—the central problem in philosophy—the only method of attack is first, as a result of critical discussion, to form a self-consistent group of instinctive beliefs, and then on that foundation logically to erect a system of thought. As, however, the instinctive beliefs of a philosopher are the result of his early environment and education, it follows that there are numerous self-consistent but mutually discrepant systems of philosophy ranging all the way from solipsism, in which existence is regarded merely as a dream, to naive realism, in which things are assumed to be exactly as they appear; and further it follows that none of these systems, on account of the a-logical character of the beliefs on which they are founded, can be shown to lead to logical absurdity. If science is to be independent of such uncertainty, it is clearly essential that metaphysical notions like physical realism and efficient causation, though hitherto regarded as essential for the purposes of science, should now be discarded. It is characteristic of this new view of science that its basic postulates are independent of the results of metaphysical thought; accordingly it is true that, *when science is regarded only as a description of our experience, such a description is valid for all men, irrespective of their philosophical leanings.*

Three fundamental postulates are implicit in our earlier discussion of the descriptive view of science. (1) It is postulated that there is a distinction between what goes on within ourselves and what happens without—the ordinary dualism of mind and matter. This assumption is provisional and methodological—that is even if philosophers should ever be able to prove that mind and matter are aspects of some underlying units, the results of science based on this postulate will still hold good. (2) It is postulated that the facts of science are merely constructs of present and past sense data. The method of systematic doubt, initiated by Descartes, seems to show in the final analysis that the only things of which we can be sure are these sense data. This assumption is also methodological, for even if philosophers can ever show that our sense data have any correspondence with some "shadowy thing in itself" behind phenomena, science will still serve to describe what are the facts for us, our sense data. (3) It is postulated that sequences of facts can be found which are describable by conceptual schemes. This assumption is basic to all knowledge; if for example we found that fire was sometimes hot and sometimes cold, or that bread was at times nourishing and at other times poisonous, we could never have developed mentally as we have, even if we could have survived so confusing an experience.

The general nature of the philosophical difficulties avoided in these postulates has been indicated in the brief discussion of each. It might, however, be well to stress further some of the philosophical implications of postulates two and three, involving as they do the rejection of physical realism and efficient causation, notions which have been of great importance in the past history of science and which are still widely held by scientists. When we perceive a table, while the scientist on the descriptive view is content to describe conceptually his sense data, the philosopher seeks to penetrate behind appearance to reality. If he is an idealist, the philosopher will regard the thing in itself, behind the sense data, as an "idea" either in the mind of God or the collective mind of mankind. If the philosopher is a realist, and in particular a physical realist, he will regard the table as composed of molecules, atoms and electrons; he will explain the sense data which he receives from the table as due to the notions and interaction of these minute, but real bodies. Now the physical realist, though he is in the minority amongst those competent to discuss such abstruse matters, may be right; but he can neither prove that he is right nor show that views divergent from his lead to logical absurdity. On account of this very uncertainty the notion of physical realism is, therefore, not retained in the descriptive view of science; on this view molecules, atoms and electrons are concepts devised by the mind of man for the sole purpose of describing phenomena. They may be "real", but such an assumption is not necessary, and is therefore not used in this view of science. Similarly the notion of efficient causation, which has previously been discussed, is not essential for the purposes of the descriptive view. Those philosophers who seek efficient causes may be and probably are right; it must, however, be admitted that in science an efficient cause has yet to be found. It is therefore sufficient to replace this notion by our third postulate, namely that sequences of phenomena can be found, so far without limit, for which conceptual description can be given. In this connection a word of caution is necessary. Plato with his "ideas", and very recently Bertrand Russell with his "universals", believed that these ideas and universals, which are none other than our concepts, formed a "real" world more important than the outside world of sense data. While they may be right, on the descriptive view of science no such assumption is necessary. On this view the concepts are regarded as purely mental inventions designed solely to describe phenomena.

In connection with the relation of science to philosophy something should be said about materialism and the denial of the existence of God. There have been and are a number of philosophers who regard the whole of experience as dictated by unalterable laws of Nature; these laws are valid from the infinite past into the infinite future and apply to the whole universe. It is these laws of Nature, which it is, so they claim, the business of science to discover; and they point to the vast achievements of science as evidence of the soundness of their philosophy. With regard to these views it may be pointed out that science has heretofore found laws applicable only to finite portions of space and valid for finite intervals of time; it is scarcely legitimate on these meagre grounds to infer the existence of laws operating over all time in the whole universe. Again the laws and theories found by science are, on the new view, purely descriptive of our experience; without some metaphysical assumptions, unnecessary for its own purposes, science cannot be regarded as discovering objective laws which Nature must obey. In fact materialism, as well as realism and idealism must stand or fall on their own merits; on the descriptive view, science cannot be regarded as lending support to any system of philosophy. Similarly the fundamental problems of theistic philosophy on the existence of God and His nature are problems to which science on the descriptive view cannot contribute. If science is, as we believe, independent of metaphysical uncertainties, it is equally true that philosophy and religion are independent of scientific achievements.

In conclusion we must recognize that the descriptive view, in spite of the rejection of the notions of physical realism and efficient causation, has served to present a self-consistent and complete picture of the purposes of science. Whatever the ultimate verdict on its value may be, a study of the descriptive view cannot fail in Pearson to stimulate and in Hobson to clarify thought on the functions of science. This article will accordingly have served its every purpose if it directs its readers to Pearson's *Grammar of Science* and Hobson's *Gifford Lectures*.

Victoria, B.C.