SCIENCE AND RELIGION*

BY PROF. ALBERT EINSTEIN, FOR.MEM.R.S.

IT would not be difficult to come to an agreement as to what we understand by science. Science is the century-old endeavour to bring together by means of systematic thought the perceptible phenomena of this world into as thorough-going an association as possible. To put it boldly, it is the attempt at the posterior reconstruction of existence by the process of conceptualization. But when asking myself what religion is, I cannot think of the answer so easily. Even after finding an answer which may satisfy me at this particular moment, I still remain convinced that I can never in any circumstances bring together, even to a slight extent, all those who have given this question serious consideration.

At first, then, instead of asking what religion is, I should prefer to ask what characterizes the aspirations of a person who gives me the impression of being religious: a person who is religiously enlightened appears to me to be one who has, to the best of his ability, liberated himself from the fetters of his selfish desires and is preoccupied with thoughts, feelings, and aspirations to which he clings because of their super-personal value. It seems to me that what is important is the force of this super-personal content and the depth of the conviction concerning its overpowering meaningfulness, regardless of whether any attempt is made to unite this content with a Divine Being, for otherwise it would not be possible to count Buddha and Spinoza as religious personalities. Accordingly, a religious person is devout in the sense that he has no doubt of the significance and loftiness of those super-personal objects and goals which neither require nor are capable of rational foundation. They exist with the same necessity and matter-of-factness as he himself. In this sense religion is the age-old endeavour of mankind to become clearly and completely conscious of these values and goals, and constantly to strengthen and extend their effects. If one conceives of religion and science according to these definitions, then a conflict between them appears impossible. For science can only ascertain what is, but not what should be, and outside its domain value judgments of all kinds remain necessary. Religion, on the other hand, deals only with evaluations of human thought and action; it cannot justifiably speak of facts and relationships between facts.

* From a written communication to the Conference on Science, Philosophy and Religion recently held at the Jewish Theological Seminary of America, New York.

According to this interpretation, the well-known conflicts between religion and science in the past must all be ascribed to a misapprehension of the situation which has been described.

For example, a conflict arises when a religious community insists on the absolute truthfulness of all statements recorded in the Bible. This means an intervention on the part of religion into the sphere of science; this is where the struggle of the Church against the doctrines of Galileo and Darwin belongs. On the other hand, representatives of science have often made an attempt to arrive at fundamental judgments with respect to values and ends on the basis of scientific method, and in this way have set themselves in opposition to religion. These conflicts have all sprung from fatal errors.

Now, even though the realms of religion and science in themselves are clearly marked off from each other, nevertheless there exist between the two strong reciprocal relationships and dependencies. Though religion may be that which determines the goal, it has, nevertheless, learned from science, in the broadest sense, what means will contribute to the attainment of the goals it has set up. But science can only be created by those who are thoroughly imbued with the aspiration towards truth and understanding. This source of feeling, however, springs from the sphere of religion. To this there also belongs the faith in the possibility that the regulations valid for the world of existence are rational, that is, comprehensible to reason. I cannot conceive of a genuine man of science without that profound faith. The situation may be expressed by an image: science without religion is lame, religion without science is blind.

Though I have asserted above, that in truth a legitimate conflict between religion and science cannot exist, I must nevertheless qualify this assertion once again on an essential point, with reference to the actual content of historical religions. This qualification has to do with the concept of God. During the youthful period of mankind's spiritual evolution, human fantasy created gods in man's own image, who, by the operations of their will, were supposed to determine, or at any rate to influence, the phenomenal world. Man sought to alter the disposition of these gods in his own favour by means of magic and prayer. The idea of God in the religions taught at present

is a sublimation of that old conception of the gods. Its anthropomorphic character is shown, for example, by the fact that men appeal to the Divine Being in prayers and plead for the fulfilment of their wishes.

Nobody, certainly, will deny that the idea of the existence of an omnipotent, just and omnibeneficent personal God is able to accord man solace, help, and guidance; also, by virtue of its simplicity the concept is accessible to the most undeveloped mind. But, on the other hand, there are decisive weaknesses attached to this idea in itself, which have been painfully felt since the beginning of history. For example, if this Being is omnipotent, then every occurrence, including every human action, every human thought, and every human feeling and aspiration is also His work; how is it possible to think of holding men responsible for their deeds and thoughts before such an Almighty Being? In giving out punishment and rewards He would to a certain extent be passing judgment on Himself. How can this be combined with the goodness and righteousness ascribed to Him?

The main source of the present-day conflicts between the spheres of religion and of science lies in this concept of a personal God. It is the aim of science to establish general rules which determine the reciprocal connexion of objects and events in time and space. For these rules, or laws of Nature, absolutely general validity is required—not proven. It is mainly a programme, and faith in the possibility of its accomplishment in principle is only founded on partial successes. But scarcely anyone could be found who would deny these partial successes and ascribe them to human self-deception. The fact that on the basis of such laws we are able to predict the temporal behaviour of phenomena in certain domains with great precision and certainty, is deeply embedded in the consciousness of the modern man, even though he may have grasped very little of the contents of those laws. He need only consider that planetary courses within the solar system may be calculated in advance with great exactitude on the basis of a limited number of simple laws. In a similar way, though not with the same precision, it is possible to calculate in advance the mode of operation of an electric motor, a transmission system, or of a wireless apparatus, even when dealing with a novel development.

To be sure, when the number of factors coming into play in a phenomenological complex is too large, scientific method in most cases fails us. One need only think of the weather, in which case prediction even for a few days ahead is impossible. Nevertheless, no one doubts that we are confronted with a causal connexion the causal components of

which are in the main known to us. Occurrences in this domain are beyond the reach of exact prediction because of the variety of factors in operation, not because of any lack of order in Nature.

We have penetrated far less deeply into the regularities obtaining within the realm of living things, but deeply enough nevertheless to sense at least the rule of fixed necessity. One need only think of the systematic order in heredity, and in the effect of poisons, as, for example, alcohol on the behaviour of organic beings. What is still lacking here is a grasp of connexions of profound generality, but not a knowledge or order in itself.

The more a man is imbued with the ordered regularity of all events, the firmer becomes his conviction that there is no room left by the side of this ordered regularity for causes of a different nature. For him neither the rule of human nor the rule of Divine Will exists as an independent cause of natural events. To be sure, the doctrine of a personal God interfering with natural events could never be *refuted*, in the real sense, by science, for this doctrine can always take refuge in those domains in which scientific knowledge has not yet been able to set foot.

But I am persuaded that such behaviour on the part of the representatives of religion would not only be unworthy but also fatal. For a doctrine which is able to maintain itself not in clear light but only in the dark will of necessity lose its effect on mankind, with incalculable harm to human progress. In their struggle for the ethical good, teachers of religion must have the stature to give up the doctrine of a personal God, that is, give up that source of fear and hope which in the past placed such vast power in the hands of priests. In their labours they will have to avail themselves of those forces which are capable of cultivating the good, the true, and the beautiful in humanity itself. This is, to be sure, a more difficult but an incomparably more worthy task. (This thought is convincingly presented in Lord Samuel's book, "Belief and Action".) After religious teachers accomplish the refining process indicated, they will surely recognize with joy that true religion has been ennobled and made more profound by scientific knowledge.

If it is one of the goals of religion to liberate mankind so far as possible from the bondage of egocentric cravings, desires and fears, scientific reasoning can aid religion in yet another sense. Although it is true that it is the goal of science to discover rules which permit the association and foretelling of facts, this is not its only aim. It also seeks to reduce the connexions discovered to the smallest possible number of mutually independent conceptual elements. It is in this striving after the rational unification of the manifold that

it encounters its greatest successes, even though it is precisely this attempt which causes it to run the greatest risk of falling a prey to illusions. But whoever has undergone the intense experience of successful advance made in this domain is moved by profound reverence for the rationality made manifest in existence. By way of the understanding he achieves a far-reaching emancipation from the shackles of personal hopes and desires, and thereby attains that humble attitude of mind towards the grandeur of reason incarnate in existence which, in its profoundest depths, is inaccessible to man. This attitude, however, appears to me to be

religious in the highest sense of the word. Thus it seems to me that science not only purifies the religious impulse of the dross of its anthropomorphism, but also contributes to a religious spiritualization of our understanding of life.

The further the spiritual evolution of mankind advances, the more certain it seems to me that the path to genuine religion does not lie through the fear of life, and the fear of death, and blind faith, but through striving after rational knowledge. In this sense, I believe that the priest must become a teacher if he wishes to do justice to his lofty educational mission.

MOLECULAR FIELDS OF FORCE: RETROSPECT AND SUGGESTIONS

BY PROF. SYDNEY CHAPMAN, F.R.S.,

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

IN the nineteenth-century development of the kinetic theory of gases, the molecules were at first usually treated as solid spheres like billiard balls, differing in size and mass. This molecular model, though it furnished a conveniently simple picture of many gas phenomena, nevertheless represented a retrogression from the model discussed long before by Boscovich¹, who regarded atoms as centres of force, varying with the distance r both in intensity and sign.

Maxwell², in 1867, made a partial return to the Boscovich model, when he gave the first mathematically accurate theory of the mean free-path phenomena of gases (namely, viscosity, conduction and diffusion), for a gas whose molecules interact according to the inverse fifth power of the distance, r^{-5} . This special law was chosen because its consequences are relatively easy to work out, within the brilliantly conceived framework of Maxwell's general method; not until 1915 was it found possible to adapt this framework so that any law of variation of the force $f(r)$, with the distance r , could be dealt with³. Soon afterwards the same results were achieved by Enskog⁴, who overcame equal difficulties in generalizing a method due to Boltzmann, itself inspired by the work of Maxwell.

Meanwhile, in 1873, van der Waals⁵ improved the solid-sphere molecular model by adding to it a field of attractive force; on this basis he developed his famous equation of state, the first great advance on the ideally simple Boyle-Charles law. Sutherland⁶, in 1893, used the same model in connexion with the theory of gaseous viscosity.

Enskog and I, in our general theories of the mean free-path phenomena, dealt particularly with the simple force-law $f(r) \propto r^{-n}$, and with the van der Waals model. Lennard-Jones⁷ first applied the theory to molecules of the Boscovich type, by taking $f(r) = Kr^{-m} + K'r^{-n}$; the first term represents the repulsive forces at short distances, and the other (if $K' < 0$) the attractions at long distances. He also calculated the equation of state for a gas composed of such molecules, and used both types of data (and others) to determine the force constants K , K' and the force indices m , n . He found that except in the case of hydrogen and helium neither the equation of state nor the viscosity determines the molecular field uniquely; for other gases the two methods permit a range of possible models (or values of K , K' , m , n), and other methods have to be used to narrow this range.

The ambiguity of the models inferred by Lennard-Jones extends even to the sign of K' , that is, it remains uncertain whether the distant field is attractive or repulsive⁸. Hence for many gases his formula for $f(r)$ may be regarded only as a means of indicating a change of the index of the repulsive field at moderate distances, instead of as representing the undoubted attraction at larger distances. If n itself is taken to be a function of r , any function $f(r)$ may be expressed as Kr^{-n} , over any range of r for which f has a constant sign; and $n = -d \log f(r)/d \log r$. For a particular temperature or range of temperature the important range of r at collisions will correspond to certain