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ARISTOTLE, NEWTON, EINSTEIN. II

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THE problem that now confronted physicists was this: How can local properties, such as a gravitational field, exist in space when the existence of an ether is not a permissible supposition? The answer was furnished, in 1915, by the "General Theory of Relativity" of Einstein. He discarded Gassendi's assumption that space was a uniform characterless vacuum, and postulated that it had a property of curvature, varying from point to point: and that just as (to make use of a rough analogy) a paramagnetic body when placed in a magnetic field tends to move from the weaker to the stronger places in the field, so a massive body in space might be pictured as moving from places of weak to places of strong curvature. The curvature, in fact, performs in general relativity the same kind of function as the density and rigidity of the ether did in classical physics; but, unlike the ether-properties, it does not come into conflict with the principle of relativity. In Einstein's conception, space is no longer the stage on which the drama of physics is performed: it is itself one of the performers; for gravitation, which is a physical property, is entirely controlled by curvature, which is a geometrical property of space.

In Einstein's theory of gravitation the Newtonian concept of force is completely done away with; a free particle moves in a path determined solely by the curvature-properties of space; it is, as the Aristotelians would say, in potency with regard to space, and things in a state of potency continually seek to become actualized. The changes of position of the particle, in their turn, bring about changes in the curvature of space, so that the particle and space together may be regarded as a single system whose evolution is determined by the law that the total curvature of space-time is to be a minimum: as we may say, gravitation represents a continual effort of the universe to straighten itself out—a statement so completely teleological that it would certainly have delighted the hearts of the Schoolmen.

While classical physics was thus being undermined by the principle of relativity, an even more devastating attack on it was developing from the side of quantum-theory. In 1913 a young Danish research student named Niels Bohr, working under Rutherford in Manchester, published some new and revolutionary ideas regarding the way in which light is generated. Let us take as the simplest example the generation of light by a hydrogen atom. This atom consists of a massive particle in the center with an electron circulating round it, just as the earth and the other planets move round the sun. Now in the solar system a planet may revolve at any distance whatever from the sun—that is to say, there is no restriction on the dimensions of the planetary orbits; and similarly, according to classical physics, the electron in the hydrogen atom might revolve at any distance whatever from the nucleus—the possible orbits would form a continuous sequence. Bohr, however, now put forward the suggestion that this deduction from classical physics is false, and that, in fact, only certain particular orbits are allowable; just as if in the solar system a planet could move in the orbit of the earth, or in that of Mars or Jupiter, but could not move in any orbit intermediate between these, such as the orbits in which the minor planets actually do move. When the electron is moving in one of the permitted orbits the atom is said to be in a stationary state; and the fundamental assumption of Bohr's theory is that the atom, when it is not emitting light, must always be in one or other of the stationary states, without the possibility of its being in any intermediate condition: the emission of light takes place when, and only when, the atom changes from one stationary state to another.

Bohr showed that his suggestion would explain many of the known features of spectra most admirably; but some serious objections could be brought against it, and one of them was that he could give no explanation of the process by which an atom in a state A is raised or lowered to another state B. In the change the electron must transfer itself from the orbit belonging to state A to the orbit belonging to State B; and according to the Gassendi-Newton doctrine, an object such as an electron can transfer itself from one position to another position only by traveling over the space between them, occupying in succession the whole continuous sequence of intermediate positions. Bohr, however, found it impossible to provide any description of the transference of the electron, and was compelled to renounce the attempt to explain transitions between stationary states. At the time, this was regarded as an imperfection in his work. In the light of our knowledge to-day, we take a very different view, and regard Bohr's renunciation as one of the most valuable and permanent features in his theory, and as a landmark in the history of science; for the subsequent development of quantum-mechanics has shown that his inability to trace the adventures of the electron between leaving orbit A and settling in orbit B was not due to any insufficiency on his part, but was inherent in the physical situation.

What is the difficulty? Is it that the mathematical operations required to calculate the motion are so intricate as to be beyond the skill of the best mathematicians? Or is it that owing to the imperfections of our laboratory apparatus we can not make measurements of sufficient delicacy to specify empirically the successive stages of the motion? No, the trouble is more deeply seated. Even if we could imagine an investigator capable of solving any set of mathematical equations whatever, and, moreover, possessing instrumental equipment of the highest refinement conceivable, even then the problem of depicting in terms of the concepts of classical physics the transition of the atom from one stationary state to another would be insoluble; and the reason is, that the process can not be described as a continuous movement of an electron in space. We are confronted by a theoretical impossibility, like the impossibility of expressing π as a rational fraction or the impossibility of constructing a regular heptagon with ruler and compasses.

The importance of this discovery is that it invalidates the presuppositions of the whole Gassendi-Newton doctrine. It shows that there are events in the physical world which can not be represented on the background of space and time.

It therefore becomes necessary to find a metaphysics different from that which has been associated with classical physics; for metaphysics must (as Aristotle held) originate with reference to physics, since it is the conceptual framework into which our experience of nature is to be fitted. The progress of science has destroyed the foundations on which natural philosophy has hitherto been grounded. How is the damage to be repaired?

Evidently space and time must be deposed from the dominant position which they held in Newtonianism, and relegated to a status more or less resembling that which they had in the Scholastic philosophy; and therefore we must now begin not with space and time, but with fundamental physical events, such as the one which has just been occupying our attention, namely, the assumption by the atom of its different possible stationary states. The atom, which has a potency of various states, is correlated to the states, as potency is to act. It endures as the atom, while it takes different states in succession. This is precisely the aspect of things on which Aristotle fixed his attention: that substratum which persists while receiving different determinations is what in the Aristotelian-Scholastic philosophy is called matter; whereas the structural principle, which is peculiar to each determination or state, is called form. The atom, then, is matter with respect to its states, which are forms.

The same principles can be applied in one of the most recent of physical theories, that of the nucleus of the atom. The nucleus is generally said to be composed of two kinds of elementary particles, called protons and neutrons; but in the quantum-mechanical theory of processes such as the emission of beta-rays, the proton and neutron are regarded as two "states" of a single entity, often called a "heavy particle." Here, then, the heavy particle would be "matter," and its determinations as a neutron or proton would be its two possible "forms."

Matter is correlated to form, as potency to act—notions which may again play an important part in the natural philosophy of the future, as they did in pre-Newtonian days.

In the light of the Aristotelian-Scholastic concepts, certain otherwise puzzling facts, which have been discovered in modern investigations, fall into their places as elements of a rational coherent system. Take, for example, the fact that all electrons have the same electric charge. For this, the classical theory of electricity has no explanation to offer: the law of interaction is that two electrified particles repel each other with a force proportional to the product of their charges and inversely proportional to the square of the distance between them; and this law is valid whether the charges are equal or unequal. Yet it is impossible to believe that the actual equality of the charges of electrons is a mere accident: it must be fundamental in the scheme of nature, and there must be a reason for it. How fundamental and necessary it is has been shown by a study of the forces by which atoms are held together so as to form molecules. Take, for instance, the hydrogen molecule, which is constituted of two hydrogen atoms, each atom consisting of a nucleus and an electron. If the two electrons are interchanged with each other, there is no change in the system, since the electrons are identical. From which feature of the situation, by following up its consequences in the light of quantum-mechanics, we can predict that a stationary state of the system exists which has less energy than the energy of the two atoms when separated: this stationary state corresponds to the stable hydrogen molecule.

In the proof, everything turns on the exact equality of the two electrons. If they had different charges, the binding force (which is purely quantum-mechanical) would not exist; and this is true of all those binding forces which are called "homopolar bonds" in chemistry. Thus the world would be a very different place from what it is, if all electrons were not identical.

But the matter is not yet exhausted. There is something more profound: electrons are indistinguishable in a still more rigorous sense. If two electrons are at one instant at places A and B, and at a later instant at places C and D, it is impossible to say which of the electrons at C and D is the one which was formerly at A—that is to say, an electron can freely exchange its recognizability with other electrons; it has no sameness of being, no proper identity, no separate history. Its selfhood is merged in an electronhood which it shares with all other electrons, and which is correlated to it as potency to act. From the philosophical point of view this is clearly important, for it necessitates a revision of the concept of individuality as applied to the elementary particles, and reopens, in connection with the most recent discoveries in physics, the question which engaged so much attention in the Middle Ages, regarding the nature of universals or general terms, which represent the common basis of a class of individual objects.

The transition which is now in progress from classical physics to a new natural philosophy conformable to relativity and quantum-mechanics is less violent than that which took place three centuries ago, when classical physics arose on the ruins of Aristotelianism, but it may prove not less significant. As we have seen, it involves a return to some fundamental Aristotelian notions, which have again become a living force; and this should lead to more intercourse and mutual understanding between men of science and philosophers; for of all types of philosophy, the Aristotelian-Scholastic is, in its principles, the most congenial to the scientific mind. Like men of science in all ages, the Schoolmen never doubted the existence of an objective world that was independent of human cognition; they were untroubled by difficulties such as those raised later by Berkeley, Hume and Kant; they looked outwards towards a reality external to themselves, and analyzed their experience of it. They held that all our knowledge is derived primarily through the senses, which come into direct contact with concrete things. The sense-impression is subjected to the operation of the active intellect, which throws light upon it, as it were, divesting it of its contingent elements and making it intelligible by drawing out the idea or concept contained in it. The idea so obtained is the means whereby knowledge is acquired. Thus the human intellect is capable of conceiving relations such as cause and effect, and of apprehending Being as such; metaphysics is possible, and completes physics by ascending to the true understanding of reality.

All this fits in very well with the scientific man's view of what metaphysics ought to be. But if the prospect of a movement in the direction of Aristotelianism is agreeable to the investigator of nature, it may prove not less so to the philosopher. For the Cartesian revolution, which dethroned Aristotle, severed the philosophic and scientific traditions from each other, and made it impossible to incorporate physics into an all-embracing doctrine of reality. The impoverished representation of the objective world which Descartes obtained by abstracting only its purely quantitative aspects was a soulless mechanism, composed of parts which had no function except to move each other about in space; and this function was itself philosophically inexplicable and had no relation to any ideas of value or purpose.

The inherent defects of Newtonianism, the result of its dependence on the concepts of Descartes and Gassendi, were perceived by Leibnitz. In his controversy with Clarke he discussed the tendency, which had become common in Newtonian circles, to conceive of the relation between God and the universe as analogous to that of a watchmaker to a watch which he has constructed, and which, having been set going, continues to function, for some time at any rate, without any necessity for the continued presence or attention of its originator. Such a conception led inevitably to the idea of an absentee God, who, having created the world, had left it to run its own course without further divine intervention and who was therefore for practical purposes non-existent. As Leibnitz saw, it is impossible to build any religion as a superstructure on a purely mechanical philosophy; and, in particular, Christianity, being an incarnational and sacramental religion, is incompatible with any view of the world which completely despiritualizes matter.

The debate between Leibnitz and Clarke took place in the lifetime of Newton, who, however, did not participate in it. Though profoundly interested in theology, he seems to have held that the physicist is not under any obligation to concern himself with metaphysics; he can give his undivided attention to investigating the laws which will enable him to predict phenomena, and can leave the deeper problems entirely out of account; he can make it his purpose to describe rather than to explain. This is one of the implications of his celebrated declaration *hypotheses non fingo*,[10] and it determined the attitude of his successors—that is to say, men of science since Newton have generally held that correct (even if in some respects limited) knowledge regarding physics can be combined with any views whatever on the fundamental questions of being and reality; that part of the world can be rightly understood without reference to the whole; that natural philosophy is independent of metaphysics.

In a restricted sense this doctrine is true. The fact can not be disputed that great discoveries regarding the behavior of the external world have been made by workers whose investigations in their field of research were not related in their own minds to any interest or belief outside it. But the effect of such segregated thinking has been to make science a departmental affair, having no influence on life and thought except indirectly through its applications. At the present time there is a movement in scientific circles aiming at securing for science a greater influence on human affairs, and even calling for a refounding of civilization on a scientific basis; but its advocates do not always understand that, as a necessary condition for the possibility of such a reform, science must be reintegrated into a unity with philosophy and religion.

[10] "Principia," *Schol. gener. sub finem.*

THE LONGEVITY OF THE EMINENT

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In an article published in the *Journal of the American Medical Association*[1] Dr. R. A. Rendich states that the most prominent physicians—those whose death notices receive the most space in the *Journal*—die on the average 4.7 years earlier in life than do those whose demise receives only a bare mention. Although Rendich presents no data which would enable a critical reader to draw any valid conclusion regarding the statistical significance of this apparent difference in longevity, Rendich assumes that the most prominent physicians really are less long-lived than are somewhat less successful physicians and he assumes further that their shortened life is the price that the prominent physicians pay for success or prominence in the medical world.

In a subsequent study,[2] Mills, who analyzed 1,036 obituary notices which were published in the same

[1] R. A. Rendich, *Jour. Am. Med. Asn.*, 119: 1041, 1942.

[2] C. A. Mills, Science, 96: 380–381, 1942.