MICROPHYSICS AND REALITY

The problem of reality has a history of which it is hardly possible to give an exhaustive account. Ontologically, reality is equated with being as such. Real means what is as it is. But epistemologically, reality is distinguished from appearance or from being so far as it is known. In the Kantian context we do not know reality as it is but only reality as it appears conditioned by the categorial structure of our thought. In the history of philosophy, not only is reality conceived differently in different contexts of different systems, but sometimes degrees of reality are posited. Reality is ascribed to the mental world or to the physical world or to both, giving rise to different schools of idealism, materialism and dualism. But reality may be denied both to what is mental and what is material with equal emphasis. Thus in the system of Plato neither the mental individualities nor the material particularizations enjoy the status of authentic being. With Plato what is real must not be subject to change and, conversely, what changes cannot be real. Hence, what is real is the super-sensible world of universal archetypes which are Ideas. The world of the senses or of the particulars is real only in so far as it participates in the eternal and immutable realm of transcendental reality. Again, on a different level of philosophical speculation reality is equated with actuality and the actual is contrasted with the possible. This has special relevance in the Aristotelian system of metaphysics where God is considered pure actuality and matter pure potentiality.

Our purpose here is not to indulge in any metaphysical speculation about reality or to go deeper into the manifold ramifications in history but only to lay bare the concept of reality in its most salient features. Little doubt that the problem of reality is rather an elusive one. We cannot hope to make much headway if we try to confront it directly. We may, therefore, approach the object of our study indirectly, in the light of recent advances in physical sciences, particularly microphysics. Scientists, like philosophers, have always been interested in the problem of reality and it has engaged their attention in no small way, forcing quite a few of them to philosophical speculation within their scientific framework. And in the present century, with the coming to light of two important theories in science, namely, the theory of relativity and the quantum theory, the problem of reality has assumed a new dimension in physics.

I

Already there is a marked tension between the idealistic and realistic interpretations of the recent revolutionary discoveries. On the one hand, an attempt is made to show that the recent developments which lay emphasis on the effective role of the observer lead to idealistic interpretations; whilst, it is held, on the other hand, that there is no warrant for any hasty conclusions and that the alternative of the ideality and the reality of the universe cannot be decided without taking into consideration all the implications of scientific research. The dilemmas before which the scientists are placed are easily discernible in what has come to be known as the Bohr-Einstein debate. The debate started in the spring of 1920 when Bohr visited Berlin and met Einstein, Planck and James Franck. The basic problem of the debate which lasted over a period of three decades, and which is at the forefront of foundational research ever since, was the question whether the quantum mechanical description of microphysical phenomena could be carried further to provide a more detailed account, as believed by Einstein, or whether it already exhausted all possibilities of accounting for observable phenomena, as claimed by Bohr. In order to come to grip with this issue, the two eminent scientists agreed on the need to re-examine the thought-experiments by which Heisenberg vindicated his indeterminacy relations and by which Bohr illustra ed the mutual exclusion of simultaneous space-time and causal descriptions. Bohr, in support of his thesis, pursued a way of thought which led him to indeterminacy relations. Einstein, on the other hand, could vindicate his stand by showing the untenability of Bohr's contention of the incompatibility of a simultaneous causal and space-time description of phenomena, thereby refuting his theory. He, therefore, set out to disprove the Heisenberg relations by a closer analysis of the mechanics of one of Heisenberg's thought-experiments. Of the thought-experiments which Einstein carried one was directed towards demonstrating that it is possible to provide an exact space-time specification of an individual process together with a detailed account of the balance of the energy and momentum transfer involved. In another 'Gedankenexperiment n which Einstein devised in collaboration with Podolsky and Rose't and which is discussed in the celebrated EPR paper "Can Quantum-Mechanical Description of Physical Reality be Considered Complete ?"[1] They arrived at conclusions counter to what Heisenberg arrived at with the help of his famous 'microscope-experiment'. EPR began their paper by pointing out that in judging the merits of any theory we have to consider (i) its agreement with human experience and (ii) the completeness which the description gives of the physical world. An attribute of a physical system that can be accurately determined without disturbing the system is an "element of physical reality", and, they argued, a description of the system is considered complete only if it embodies all the elements of reality which can be attached to it. In the experiment they devised they have shown that for a certain system composed of two particles, P_1 and P_2, a measurement of the momentum of P_1 allows one to predict with certainty the momentum of P_2 without in any way disturbing P_2, and, that a measurement of the position of P_1 allows one equally well to predict with certainty the position of P_2, again without in any way disturbing P_2. Now, since the position and the momentum of P_2 can be obtained by appropriate measnrements performed on P_1, without in any way disturbing P_2, according to the "criterion of reality"[2], elements of reality correspond to both the position and the momentum of the particle P_2. And since quantum theory does not allow both to enter into the description of the state of the particle, such a description is essentially incomplete. EPR concluded their paper on an optimistic note, in keeping with Einstein's "Scientific instinct": "While we have thus shown that the wave function does not provide a complete description of the physical reality, we left open the question of whether or not such a description exists. We believe, however, that such a theory is possible."[3].

Einstein and his collaborators always regarded their argument as conclusive evidence for the incompleteness of the quantum-mechanical description of physical reality. In his "Reply to Criticisms"[4], Einstein explicitly reaffirms, notwithstanding the objections raised by Bohr and others, the view expressed in the EPR paper. Fifteen years after the EPR paper, Einstein wrote to

Schroedinger that he felt that " ...... the fundamentally statistical character of the theory is simply a consequence of the incompleteness of the description "[5]. At another place faced with sustained criticism he expressed himself thus : " I still work indefatigably at science but I have become an evil renegade who does not wish physics to be based on probabilities "[6].

It appears odd that Einstein, who had contributed so significantly to the development of statistical methods in physics, should oppose with such uncompromising vehemence the basic tenet of quantum mechanics. The answer seems to lie in his deep philosophic conviction, his " scientific instinct ", that statistical methods, though of great use as a mathematical device for dealing with natural phenomena that involve large numbers of elementary processes, could not give an exhaustive account of the individual processes. It was this conviction that prompted him to write in a letter to Born, that he " could not believe in a dice-throwing God. "[7]

II

Niels Bohr could not accept the epistemological criterion of physical reality as proposed by Einstein, Podolsky and Rosen, claiming that it contains " an essential ambiguity " when applied to phenomena in quantum mechanics. In a paper[8] which appeared shortly after the EPR parer and which carried the same title as the EPR paper, Bohr pointed out that the ambiguity lay in the EPR criterion of reality, specifically in the expression " without in any way disturbing a system ". No doubt, in the case of two particles, P_1 and P_2 a measurement performed on the particle P_1 does not cause any physical disturbance to the particle P_2, but, argued Bohr, the fact remains that it does affect basically the kind of verifiable statement that we can make about P_2; our rational expectations of possible happenings are invariably conditioned by our knowledge of circumstances in which the happenings take place. Each measurement made on the particle P_1 defines a different phenomenon in so far as the same system of two particles is observed under different conditions. By observing the position of the particle P_1, we can, no doubt, ascertain the position of the particle P_2 by consideration of the correlation between the positions of the two particles. But, then, we know no means by which we can ascertain the correlation between the momenta of the particles; for, as enjointed by Heisenberg's indeterminacy principle, by measuring the position of the particle P_1, we have lost control over its momentum. And, in a measurement like this, there takes place an indeterminate exchange of momentum between the particle and the measuring instruments. Similar considerations lead us to conclude that if we measure the momentum of the particle P_1, we know the momentum correlation alright, but the position correlation is simply indeterminable. These two measurements constitute what are called " complementary " phenomena. Bohr writes in the article : " ... ...the renunciation in each experimental arrangement of the one or the other of two aspects of the description of physical phenomena, – the combination of which characterizes the method of classical physics, and which therefore in this sense may be considered as ***complementary*** to one another, depends essentially on the impossibility, in the field of quantum theory, of accurately controlling the reaction of the object on the measuring instruments, i. e., the transfer of momentum in case of position measurements, and the displacement in case of momentum measurements."[9]

In fact, Bohr maintains that the object under observation and the measuring instruments form a single indivisible system not susceptible to further analysis at the quantum-mechanical level into distinctly separate parts. And the description of the state of a system expresses a relation between the object under observation and the entire experimental setup, rather than being confined to the object alone. No doubt, this correlation between object and measuring apparatus exists even in classical physics. But there the two systms can be distinguished by an appropriate conceptual analysis. In quantum mechanics, on the other hand, no such analysis is possible, object and measuring apparatus forming an unanalysable whole. Whereas in classical physics the interaction between object and measuring apparatus may be neglected or compensated for, in quantum mechanics it is inextricably linked with the phenomenon. The " feature of wholeness " thus comes to the rescue of Bohr's view of the completeness of quantum-mechanical description : " In the case of quantum phenomena, the unlimlted divisibility of events...........is, in principle, excluded by the requirement to specify the experimental conditions. Indeed, the feature of wholeness typical of proper quantum phenomena finds its logical expression in the circumstance that any attempt at a well-defined subdivision would demand a change in the experimental arrangement incompatible with the definition of the phenomena under investigation."[10]

Bohr, thus, maintains that the general structure of the quantum theory is not compatible with the familiar and indeed traditional descriptions based on the assumption that the subject-matter of physics is a system whose properties are observed or measured by independent observer or measuring instrument. He took pains to insist that for quantum mechanics there could be no atomic object to be observed by a separate observer, and he never thought in terms of two such systems divided by any separation between them. Indeed, any reference to such a separation would be inconsistent with his " feature of wholeness ".

III

These insights of Bohr coupled with deep philosophic convictions of Einstein may enable us to find some content behind the problem of reality. Now the general structure of our language is such as to involve separate existence of each thing. All relationships of things are made intelligible only through the subject-object structure. A subject is assumed to act on an object, or simply to carry out an action, or else it is said to possess certain attributes or qualities. Such a language form implies the possibility of a complete separation between a thing and what it does or what qualities it has. This separation is basically verbal in origin. But since it tends to be incorporated into the general form of almost all our perception, we have, for the most part, lost sight of its essentially verbal character and have ventured to attribute it a non-verbal status.

However, this separation[11] cannot survive a careful scrutiny. If, for example, one could make an effort to abstract a human being from all his attributes and qualities and to separate him from all the acts through which he participates in life, what would he be ? Evidently, a philosophical non-entity or an ontological vacuum

However, our language structure implies that such a human being is a subject or a 'self', who somehow possesses all these attributes and qualities, and carries out all these acts accidentally. Obviously, if this 'self' is shorn of all its 'possessions', one wonders if anything would be left which transcends all that was supposed to belong to it. Thus without arrogating to ourselves the right to dispute the metaphysical status of the 'self' (a question which is deeply rooted in man's non-rational involvements) we may, by extending the chain of Bohr's reasoning, conclude that the importance which the word 'self' has come to assume in philosophical literature is mainly because of our peculiar language structure. Language is to be regarded as an inseparable aspect of one single process which includes perception as well as action. Since all aspects of existence are inseparably intertwined, our language must adequately take account of this fact. What is needed, therefore, is to develop a more clear languge structure which will allow us to talk of reality in a consistent frame of reference.

An act of abstraction precedes every judgment about reality. Reality, indeed, in all its totality, is only an Idea in the Kantian language, which cannot become the object of our judgment, but only in so far as it is abstracted in the relevant context. Evidently even the totality of what we perceive and what we know, not to speak of the immeasurably greater totality of all that is, is so vast and varied that it cannot be exhaustively described. Nature is constituted of an inexhaustible diversity and multiplicity of things, all of them reciprocally related and all of them necessarily taking part in the process of becoming. As a result no concrete manifestation can be more than an abstraction from this process–an abstraction that has relevance within a certailn degree of approximation, in definite ranges of conditions, within a limited context, and over a characteristic period of time. Such an abstraction, evidently, by the requirements of its very nature, cannot be exhaustive in its reference. This would imply that the scientific research cannot lead to a knowledge of nature that is complete and that needs no further improvement or extension. Rather it involves us in an unending process in which there may be a constant approximation to truth. For any given law of nature, we can never determine all the deviations from it completely. As a result we can never actually reach an absolute precision with regard to the law. And, in the same way, with regard to nature as a whole, we cannot maintain that the continual process of narrowing down of deviation from our theories will, through a series of succcssive approximations, ever converge on some fixed and final goal. For, as science advances, we find that the awareness of inadequacy in previous theories consistently points towards the discovery of dimensions hitherto unknown. In addition, for any given stage of knowledge, there are aspects which are not significant in contexts and conditions studied in that stage, but which may well be of crucial importance in new contexts and conditions.[12] As a result, the goal of an absolute precision of knowledge in all possible contexts and conditions keeps on receding and new horizons appear before us as we continue to penetrate more and more and in manifold ways into the inexhaustible characteristics of nature. We cannot but recognize the limitations of our knowledge and we cannot say that all we know at present and all we can know has reached its culmination or will ever reach its fulfilment. Epistemological limitations do not allow our knowledge of reality at any stage of its development to be equated with the ontological structure of reality itself.

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Notes

1. A. Einstein, B. Podolsky and N. Rosen, "Can Quantum-mechanical Description of Physical Reality be Considered Complete?", *Physical Review*, 47 (1935), pp. 777-780. Reprinted in *Physical Reality*, Stephen Toulmin, (ed.) (Harper Torchbooks, New York 1970), pp. 123–130.

2. EPR gives a sufficient condition for physical reality : "If, without in any way disturbing a system, we can predict with certainty (i. e. with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity". S. Toulmin, (ed.) *Physical Reality*, p. 124.

3- S. Toulmin, (ed.), *Physical Reality*, p. 130.

4. P. A. Schilpp, (ed.), *Albert Esintein : Philosopher-Scientist* (Library of Living Philosophers, Evanston, III., 1949), pp. 663–688.

5. Schroedinger, Planck, Einstein, Lorentz, *Letters on Wave Mechanics*, K. Prizbram, (ed.) (Philosophical Library, New York, 1967), p. 10.

6, M. Born, *The Born-Einstein Letters* (Walter and Co.. New York, 1971), p. 163.

7. Ibid.

8. N. Bohr, " Can Quantum-mechanical Description of Physical Reality be Considered Complete ? " *Physical Review*, 48 (1935), pp. 696–702. Reprinted in *Physical Reality*, Stephen Toulmin, (ed.) (Harper Torchbooks, New York, 1970), pp. 130–142.

9. S. Tolumin, (ed.), *Physical Reality*, p. 136.

10. N. Bohr, " Quantum-physics and Philosophy " in N. Bohr, *Essays 1958–1962 on Atomic Phnsics and Human Knowledge* (Interscience, London, 1963), p. 4.

11, Cf. D. Bohm, " Classical and Non–Classical Concepts in the Quantum Theory " in *Physical Reality*, S. Tolumin, (ed.) (Harper Torchbooks, New York, 1970); p. 200.

12. David Bohm has brought out this point very clearly in his book, *Causality and Chance in Modern Physics* (Routledge and Kegan Paul, London, 1957). See for example, the analogy on pp. 79–80.