BEYOND QUANTUM THEORY: A REALIST PSYCHO-BIOLOGICAL INTERPRETATION OF PHYSICAL REALITY *

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ABSTRACT

Stapp and others have proposed that reality involves a fundamental life process, or creative process. It is shown how this process description may be unified with the description that derives from quantum physics. The methods of the quantum physicist and of the biological sciences are seen to be two alternative approaches to the understanding of nature, involving two distinct modes of description which can usefully supplement each other, and neither on its own contains the full story. The unified view explains the major features of quantum mechanics and suggests that biological systems may function more effectively than would be expected on the basis of quantum mechanics alone.

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1. INTRODUCTION

The thesis developed in this paper is that the quantum domain and the domain of life processes are closely related and indeed inseparable from one another, a relationship of which kind has been suggested in a number of recent publications.(1-3) These proposals depart from orthodoxy by postulating that a phenomenon whose general nature is that of a life process underlies all natural phenomena, and then attempt to account for certain features of the quantum domain on such a basis. A related idea is developed in some detail in what follows, to the effect that there exists in the natural world a quantum mechanical/biological dualism, analogous to the wave-particle dualism found in the ordinary quantum domain. The methods of the quantum physicist and of the biological sciences are seen as two alternative approaches to the understanding of nature, involving two distinct modes of description which can usefully supplement each other (cf. Leggett(4)), neither of which contains on its own the full story. Our unified approach to the description of natural phenomena shows how it may be possible that the apparent advantage of the quantum mechanical approach, namely that it provides predictions of a precise nature, may be offset by its corresponding disadvantage of dealing with nature only in statistical terms. In terms of a simple analogy involving a classical fluid that we shall make use of in what follows, quantum theory corresponds to statistical mechanics, while process-type descriptions correspond to descriptions involving the characteristics of individual atoms.

2. THE CHARACTERISTIC DIFFERENCES BETWEEN THE TWO CATEGORIES OF DESCRIPTION

We discuss first the contrasting approaches of the two disciplines, quantum-physical and biological. The characteristic differences between the two approaches largely account for the fact that these two distinct types of description of nature exist.

Quantum mechanics is a theory of nature founded on the philosophy that one ought to be able to assign a precise, quantitative description to the systems of interest. Such a view, while satisfactory in the case of many kinds of systems studied in the physics laboratory, does not seem to be suitable for the case of biological systems. These have an intrinsic variability which cannot be characterised in full in terms of any kind of measurement or preparation procedure. It is impossible to give a biological system a quantum-mechanically precise specification (in the way we can write down the ground state of a molecule or a superconductor to a good approximation), or to predict its properties with high accuracy (a state of affairs already noted by Bohr).(5) What can be done, however, as is normally done by biologists, is to specify biosystems in descriptive terms involving variables of a more global nature, and to determine what are the important processes relevant to explaining some of the observed properties.

We note also that quantum mechanics is a highly formalised theory in which all contact with actual phenomena has to go via the quantum theory of measurement; this makes it very difficult to talk in a technically correct way about what is actually happening in the system of interest. Again, this is less of a problem with biological descriptions in terms of processes, which being a looser form of description circumvent the difficulties of principle which are associated with precise descriptions.

In practice, biology and quantum mechanics work together and complement each other. Biology borrows results from physics and chemistry to obtain explanations for biological phenomena, thus explaining them with some degree of quantitative accuracy. Nevertheless, the fact remains that quantum mechanics is precision- oriented and biology process-oriented, and that to some extent the two goals are incompatible with each other.

3. WAVE-PARTICLE DUALISM AND QUANTUM MECHANICAL/ BIOLOGICAL DUALISM

The meaning of the word dualism in the quantum mechanical context is that in some situations we can find phenomena such as diffraction which are well described by a wave picture, while in other situations we find instead phenomena, such as the photoelectric effect, which are best fitted by a particle picture. The initial reconciliation of these two apparently incompatible forms of description came in the first instance from de Broglie's demonstration that the motion of an electron in an applied field could be understood perfectly well in terms of a wave picture (i.e., in terms of wave packets), provided one made the appropriate identification of wave and particle properties such as that given by the de Broglie relationship connecting wavelength and momentum. This situation (i.e. the one of the computation of trajectories) is one where either description, wave or particle, may be used equally well; the two descriptions are not, as is usually the case, complementary in the sense of being mutually exclusive, and they are related to each other in accordance with de Broglie's prescriptions.

Turning now to proposals such as those of Stapp(1) (and especially his proposal that the phenomenon of state vector collapse in the domain of quantum mechanics can equally be viewed as a phenomenon in the field of mind, namely a decision process), we find an analogous situation: that there is a domain of reality where some phenomena can be viewed within two alternative frames of reference, here the quantum mechanical and the biological.

In the wave-particle dualism case, a mathematical derivation connecting the two pictures can be given. While we are unable to provide a similar mathematical derivation for the situation of interest here, we are able to make a consistent set of proposals concerning which entities connect up with each other in the two pictures. These proposals, which extend those of Stapp and the other authors cited, are shown in Table 1.

LANGUAGE OF QUANTUM PHYSICS		**LANGUAGE OF BIOLOGY**
quantum subsystem, describable by a state vector	↔	signal or form
particle type	↔	type of signal or form
state vector representing a specific possibility	↔	signal representing a specific possibility
collapse of state vector	↔	decision process
measuring instrument determining state of subsystem	↔	structures which determine and regulate signals or forms

Table 1. Proposed identification of entities described in terms of the respective frames of reference of the quantum physicist and the biologist.

In the proposed correspondence, we begin by assuming that a quantum subsystem, such as an electron which is to a first approximation isolated, translates into what in the biological picture would be regarded as a signal. We note that signals in biosystems are superposible in the linear regime, as are state vectors of quantum subsystems. The motivation for choosing this particular assignment in the correspondence is that signals in biological systems and state vectors of quantum subsystems both constitute indications, and in some cases very specific indications, of possibilities for the future. For example, a peak in an electron wave function is closely correlated with the possibility of observing an electron in the region of the peak, while, in the biological domain, the nervous system activity corresponding to the planning process may implicate within itself a very specific action in the future. We can go further with the correspondence by noting (following Stapp) that the processes of collapse of a state vector in a quantum system and decision in the field of mind share the feature that they involve the selection of one alternative out of many. There are specific contexts in which these processes are particularly liable to occur; measurement in the quantum domain and information processing in the biological domain. Hence we connect measuring instruments in quantum mechanics, which shape the state vector, with the structures in biosystems that determine and regulate signals or forms.

We see that there is a scheme of connection between the two regimes which preserves many or all of the essential non-quantitative features and also links features of the quantum domain which have to be simply postulated with features of living systems which can be explained in detail in many instances. If such a link could be shown to be in fact soundly based, it would then be valid to state that these features of the quantum domain were actually explained by the corresponding biological arguments. We hypothesize that a theory based on a more comprehensive understanding of the situation would validate the proposed connections in a way analogous to the way in which de Broglie and those who succeeded him demonstrated the connection between the wave and particle pictures at the quantum level.

4. EMERGENCE OF BIOLOGICAL AND QUANTUM PROPERTIES FROM A SUBTLER LEVEL

The picture we have developed so far is that certain aspects of the domain which is described by the quantum theory may arise by virtue of mechanisms found in biological systems. We now wish to discuss the complementary features of the quantum and the biological domains in more detail and in particular consider the question of how both domains of description may emerge by somewhat different mechanisms from a common substratum. We shall discuss first the processes by which biological characteristics can emerge in the context of the presumed deeper level. These are presumed to be essentially identical to those by which the organisation characteristic of ordinary living systems comes into existence. One dominant feature of the domain of living systems is the existence of information sources, such as DNA or neural impulses, which can have a strong controlling influence on the nature of the forms that will be created within or by a biological system, and on the general activity of the system.

Two different mechanisms by which the information sources come into being can be distinguished. One of these is mutation combined with natural selection, which causes the evolution of information sources that are particularly useful from the point of view of survival to occur. The second category depends on rather more subtle processes involving self-organisation, found, for example, in processes of morphogenesis, development, and learning. Typically, such a process involves assessment of the performance of a particular function, with subsequent modification of the controlling information source (or of the system being controlled itself), in accordance with a specific appropriate procedure or algorithm whose effect is to generate a corresponding improvement in the performance of the given function. Such a feedback process determines not the precise details of the structure, but instead the functioning of the system at a general level (known as the phenotype). There is even more variability at the more detailed genotype level than is encompassed by the arguments given so far, since different information sources (genotypes) may give rise to the same general functioning (phenotype), as long as this general functioning makes a sufficient contribution to the fitness of the organism that natural selection can select for genotypes conducive to this functioning. It was noted also by Bohr(5) that, in view of the disturbances produced by measurement in the quantum mechanical domain, one could not expect to measure the microscopic details of biosystems without disturbing them in essential ways. These arguments give a logical basis to our previous proposals to the effect that biosystems are amenable to general descriptions but not to precise ones.

The general features of biological organisation that have just been discussed (which are the basis of such features as the use of signals and the existence of planning and decision processes, which feature on the right-hand side of Table 1) are independent of the details of the underlying physics and could be present equally well if there were an underlying physics deeper than that described by quantum physics. We make the assumption that such a deeper level exists, because it is then possible to account for the corresponding features on the left side of Table 1, by assuming the situations described by quantum mechanics to be a particular case of a more general situation (just as particle trajectories are explained by de Broglie's arguments as a special situation within a more general picture in terms of waves). This assumption could not be made if we were to take the usual view that all natural phenomena could be accounted for on the basis of the axioms of quantum mechanics alone.

We now discuss in general terms how quantum mechanics might arise as a special case. We interpret the state vector as a description of a collective mode, whose existence is dependent on the presence of a sufficiently regular substructure (in the way that, for example, spin waves in ferromagnets depend on the background being magnetically ordered). Hilbert space is interpreted as the space of all such collective modes, which in a biological context manifest as signals. The quantum vacuum state, since it is represented by a specific vector in Hilbert space, is interpreted as a specific collective mode of the system rather than as no oscillation at all, and particles correspond to various kinds of modulation of the special oscillation that corresponds to the vacuum state, with the operators describing these modulations having the same interrelations with each other (in terms of their commutation relations, and transformations under symmetry operations, for example) as do particle creation and annihilation operators in quantum field theory.

In quantum mechanics the idea of a classical domain plays an essential role, since only it is presumed to be knowable directly. In the viewpoint of the present paper, the difference between the classical domain and the quantum domain is considered to be one of degree only. The significant differences between the quantum domain and the classical domain follow from the fact that features at the quantum level are very sensitive to disturbances, while those at the classical level are not.

In accordance with the general scheme proposed in Table 1 for translating between the two languages, what is seen from the biological view as a decision process is described in quantum language as the collapse of the state vector. Quantum mechanics describes the collapse process mathematically, but does not explain the process in detail, as may be possible in the biological picture which may be able to take into account factors not correctly describable in the statistical formalism of quantum mechanics.

5. KNOWLEDGE AND MEASUREABILITY

The last remark brings us naturally to questions relating to measurablity. Measurement is a process characterised by the fact that some feature of a system of interest becomes correlated with a feature of a system which is sufficiently macroscopic as to be observable with the senses (via intermediate amplification processes if necessary). In the quantum domain the measurement process reflects back drastically on the system being measured. The projection postulate of quantum mechanical measurement theory shows that the measuring instrument acts as a filter whose setting depends on the state of the measuring instrument after the measurement interaction. The correlate of this assumption in the biological language (cf. Table 1) is the registering by an information processing system of the decision process that it has just carried out.

It should be noted that in the current interpretation we do not assert that such processes as the state vector collapse associated with quantum measurement are purely formal or imaginary and have no corresponding physical correlates. Instead we assume the mathematical filtering operation to correspond to a real physical process the detailed nature of which may become clarified when the biological aspects of the unified theory are taken fully into account. We remark also that the Aspect experiment, based on the theoretical discussion of Einstein, Podolsky, and Rosen, suggests that this filtering process may act nonlocally, or at any rate that some kind of distant physical connections must exist in the quantum domain.

In science, measurement is the fundamental agency through which knowledge is acquired. Quantum mechanical measurement theory is one particular theory of measurement, which in the Copenhagen school of quantum mechanics has been elevated to the status of a theory of all conceivable measurement processes. However, the formal apparatus of quantum mechanics imposes strong limitations on its ability to describe experiment. We recall that, within the framework of quantum mechanics, systems are specifiable only by "quantum mechanical measurements", defined as measurements which can be precisely associated with particular Hermitian operators. There is no real reason why all information-gathering devices, and in particular devices based on different concepts as to what kind of information is being gathered, should fit into this particular formal scheme. This theme may be illustrated with an analogy which will prove useful later, consisting of a gas composed of classical atoms or molecules. Because of the phenomenon of chaos, the detailed behaviour of the gas is essentially unpredictable except for very short time scales, but in certain regimes various phenomena emerge which are practically predictable on the basis of the appropriate scientific laws. The two regimes that are relevant in the case of a gas are the one of macroscopic laws (such as those of hydrodynamics) and the one concerned with the behaviour of individual atoms in a collision-free situation.

From the viewpoint of macroscopic theories of gases, measurement consists purely of measurements of macroscopic quantities such as those of the local density, pressure, and temperature; and one could imagine there existing on another planet, where science developed differently, a Copenhagen-type school expounding the doctrine that all possible measurements in gases were of this type, and maintaining on this basis that the macroscopic equations of gases (combined with phenomenological equations to describe fluctuation phenomena) formed a complete description of the outcome of all possible experiments. In accordance with this point of view, all speculation concerning atoms could be dismissed as being of philosophical interest only. In this fanciful analogy it is presumed, naturally, that the other sources of evidence for the existence of atoms, such as those based on chemistry, were unknown to our hypothetical scientists.

This hypothetical example shows us clearly how a new concept of what can be measured can change the content of science, as happened historically when experiments focussing on the properties of atoms as individual entities became technically feasible. We shall take the view here, implicit in what has already been said, to the effect that nature does not in general fit exactly into any particular prescribed scheme of description or measurement: describability is context-dependent, and it is only in special circumstances (which may in some cases be created by the actions of the experimenter) that phenomena emerge which fit into a particular scheme.

6. AN ARGUMENT FOR BIOLOGICAL INVESTIGATIONS TRANSCENDING QUANTUM MECHANICS

Biosystems are an area where the considerations of this paper may be particularly relevant. Again we refer to the analogy with a *classical* gas that was used to expound our proposed dualism between quantum mechanical and biological descriptions. In descriptions of a classical gas based on statistical mechanics, quantities such as density fluctuations are described only in statistical terms. In the framework of the atomic description, on the other hand, they can in principle be described exactly. By analogy, one might expect it to be possible to obtain more accurate descriptions (and hence also predictions) of particular quantities in biological systems using biological descriptions than using the methods of quantum mechanics. Consider in particular the following scenario: the level of performance of a skill depends on very specific subtleties of structure that are individual to each system. These subtleties are not of the kind that can be encompassed within the descriptions of the quantum theory (which are assumed to relate to simpler, collective behaviour). Quantum theory fails to describe the subtleties for essentially the same reason that hydrodynamics fails to describe the behaviour of individual atoms. It will therefore equally fail to describe correctly any behaviour which is critically dependent on these subtleties. Because the general effect of evolution has been in the direction of modifying the relevant parameters so as to optimise performance, the anticipated effect of any inadequacies of the quantum theory is that biological systems may function *more effectively* than would be predicted from an exact quantum mechanical calculation.

It might be assumed that the successes achieved hitherto in the domain of biology using theories based on quantum mechanics would argue against such a state of affairs. In fact, current applications of quantum mechanics to biosystems do not really test for the existence of such effects, because of the degree of approximation that is involved in the theories concerned. In effect, in such calculations all physical systems above the molecular level of organisation are normally treated in classical terms. Level of performance in biosystems is therefore one area where our ideas may have important implications for the future.

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FOOTNOTE

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