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Biological Utilisation of Quantum NonLocality[1]

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The perception of reality by biosystems is based on different, and in certain respects more effective principles than those utilised by the more formal procedures of science. As a result, what appears as random pattern to the scientific method can be meaningful pattern to a living organism. The existence of this complementary perception of reality makes possible in principle effective use by organisms of the direct interconnections between spatially separated objects shown to exist in the work of J.S. Bell.

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1. INTRODUCTION

Bell(1,2)[4] has given arguments that appear to demonstrate the existence of direct interconnections between spatially separated objects. But at the same time there are arguments(4-6) that appear to show that no real physical manifestations of these interconnections actually exist. The thesis developed in this paper is that it is only from the point of view of quantum mechanics that these connections appear to be unphysical, and that there is a different, complementary point of view, one associated specifically with the activities of living organisms, in terms of which the interconnections may be very concretely real, and capable of being put to practical use.

The logic of the complementary point of view to which reference has just been made is that the activities of living organisms are governed by predominant principles (survival, and optimality of the conditions of life) different to those of the scientist (conformity to certain restrictions that are considered necessary for "good" science). The perceptual processes of organisms (e.g. processes such as vision) perform their functions in general very effectively, but in a way that is hard to delineate in rigorous scientific terms. It will be argued that as a result of this difference the knowledge possessed by biosystems and the knowledge possessed by science are qualitatively different, leading to an ability of life to make use of Bell's non-locality in a way that is not possible in the different situation of a controlled scientific experiment.

The discourse that follows begins (Sec. 2) with a review of Bell's theorem, discussing in particular the antithesis between the way that Bell's argument appears to demonstrate the existence of direct action at a distance, while at the same time quantum calculations lead to the result that any such effects will disappear under statistical averaging. Experiments on certain unusual human abilities(7,8) suggest that the non-local effects do not invariably disappear under averaging, a result that the present paper seeks to explain.

The explanation proposed here involves the issue of exactly what kind of randomness is being presupposed when one performs such statistical averaging. An answer to this question in general terms is provided by causal (non-statistical) models of the phenomena of the quantum realm such as that of Bohm(9). This kind of interpretation assumes the relevance of particular probability distributions in an appropriate phase space. The possibility that one needs in general to deal with coexisting multiple representations of reality (complementarity) is then considered, the implication being that different kinds of probability distributions to those relevant to quantum mechanical predictions may be appropriate in cases such as those involving biosystems. From the point of view of a biosystem itself, this possibility translates into one that biosystems can have more discriminative knowledge of nature than is obtainable by quantum measurement. As a result of this higher degree of discrimination, the evolutionary and developmental processes characteristic of biosystems can, given suitable initial conditions, lead to focussed probability distributions that make possible the kind of human abilities (i.e. psi functioning) to which reference has been previously made.

2. BELL'S THEOREM AND NONLOCAL CONNECTIONS

We first review Bell's theorem. Its domain of relevance is of a type of system, which we shall refer to here as an EPR-type system, first discussed by Einstein, Podolsky and Rosen(10). EPR-type systems are systems wherein a quantum object breaks up into parts which after separating are observed by measuring instruments that have no links of a type that can transmit information by normal means to each other. A typical example of such a system, which has been studied experimentally(11), involves measurement of the correlated polarisations of the photons emitted in a two-photon decay sequence. Bell's theorem consists of an inequality applicable to the correlations observed in a range of different measurements, and from it one can derive the corollary that no local model of physical reality can exist whose statistical predictions would be in agreement with those of quantum mechanics: in Bell's own words(1), if nature behaves in accordance with the statistical predictions of quantum mechanics then "there must be a mechanism whereby the setting of one measuring device can influence the reading of another instrument, however remote". Experimental results, while not being totally conclusive, are such as to point towards this conclusion being valid.

The existence of such remote influences or connections is suggested more directly by experiments on phenomena such as telepathy (the direct connection of one mind with another) and psychokinesis (the direct influence of mind on matter), both of which are examples of so-called psi functioning or psychic phenomena. The reader interested in learning about these phenomena (which are often disregarded by orthodox science) is referred to the recent article by Radin and Nelson(8) which analyses experiments relating to them, as well as to the references cited therein (and especially those relating to the publications of R.G. Jahn and collaborators, and of H. Schmidt), and to Ref. 7[5].

3. DO THE INTERCONNECTIONS PERSIST UNDER STATISTICAL AVERAGING?

Ordinary quantum mechanical calculations, if one excludes from consideration proposals such as that of Walker(12) that contain special ad hoc modifications to the conventional theory, do not seem to provide any clear mechanism leading to the occurrence of phenomena where the effects of non-local connections are manifested directly. Indeed, conventional quantum mechanical calculations(4,5) suggest that whatever effects changing the setting of a measuring device may have on *individual* remote events, the *statistical distribution* of such events remains unaltered. Mermin(6) concludes as a result that "The manifestation of this 'action at a distance' is revealed only through a comparison of the data independently gathered at A and at B" (the locations of the two measuring instruments). He characterises the measurements carried out at the remote location as being "entirely random".

But what is "entirely random"? What appears to be random in a given situation depends on the context, on what one knows and on one's point of view. Coded messages, the roll of a die, output from a computer, or the movements of a person operating a piece of machinery may all appear random if one does not know the relevant details (the code that is used in the coded message, the exact manner in which the die is thrown, what the computer program or piece of machinery is and what it is doing) and yet if one knows this information many of the details of such phenomena can be understood. An alternative description of microphysical reality to that provided by quantum mechanics, if any such exists, may be associated with a different kind of statistical average. What seems to be noise may no longer be noise, and the theorem implying no manifestations of interconnectedness for the statistical average may no longer apply.

But do situations actually exist in nature whose descriptions involve less randomness in particular aspects than quantum mechanics implies? In the past, it might have been stated unconditionally that von Neumann had under very general conditions disproved the existence of such a possibility, but it is now recognised(13) that the supposed proofs of these assertions contained assumptions that are in fact unjustifiable. There exist arguments(14-17) that complementary descriptions to those of quantum mechanics can and in all probability do occur. Detailed discussion of this issue will play a central role in the analysis that follows.

4. CAUSAL INTERPRETATIONS OF QUANTUM MECHANICS

In the context of the present problem it is useful to think in terms of causal interpretations of quantum mechanics. These are models where the observed indeterminacy is a consequence of uncertainty of the actual state of a system whose dynamical laws in themselves are completely deterministic. Bohm's causal model(9) involves an ensemble of particles distributed in phase space with a particular self-consistent probability distribution function and moving in accordance with certain deterministic laws. The statistical predictions of quantum mechanics are reproduced exactly in a way that avoids the usual introduction of unclear and arbitrary assumptions concerning measurement, wave function collapse, or separation of a system into observer and observed. The non-locality which Bell showed to be implicit in quantum mechanics is *explicit* in Bohm's causal model, in that the motion of the particles in the model is governed by an interaction, determined by the quantum wave function of the system, that is non-local.

In most common situations, averaging over the particle positions in the causal model makes the mean direct influence of one particle on another at large distances negligibly small. This is not so, however, in EPR-type situations where the wave function has a non-decomposability property which makes this interaction at a distance significantly different from zero even at long range(13). But, even in these situations, once we take an ensemble average, using the special distribution function in phase space that assures the statistical equivalence of the causal interpretation and quantum mechanics, we revert to the quantum mechanical prediction that statistically no influence at a distance can be demonstrated. One may ask, however, why only these special distribution functions should apply. Is there anything absolute about the ignorance implicit in the use of these particular distribution functions? The argument will be made in the following that other distribution functions, with different statistical properties, are relevant in other contexts, especially those associated with life.

Situations where a change in context leads to a new kind of statistical distribution becoming relevant are indeed commonplace in science: they occur for example whenever a phase transition occurs that leads to a breaking of symmetry. As a result of symmetry breaking, statistical distributions that are *asymmetric* with regard to this symmetry may come into existence in situations where previously only symmetric distributions were observable or relevant. Analogously, it can be anticipated that special situations will exist whose natural description involves probability distributions other than the particular ones that arise in the *quantum formalism*.

5. MULTIPLE DESCRIPTIONS OF REALITY

We now discuss in some detail this idea that rather than a single, universal, description of reality (such as that provided by quantum mechanics) being appropriate in all circumstances, more than one complementary or alternative form of knowledge may exist(14-17). This state of affairs is most simply understood with reference to a special feature of the quantum domain related to quantum indeterminism, which we shall characterise as the *loss of universal determinism*. This latter term is intended to reflect the fact that in this domain quantum indeterminism renders impossible the making of exact predictions on the basis of a *universal formula* (which would be possible in principle in classical physics if the relevant dynamical laws such as Maxwell's equations or Newton's laws were known). We hypothesise that two alternative strategies are possible for dealing with the loss of universal determinism. The first, the method of science, is to retain conformity with the demands of reproducibility and universality by the device of replacing the no longer possible strict determinism by *statistical determinism*. The outcome of this approach is quantum mechanics. The second, a method that is in general terms favoured by life, involves renouncing the demand for universal knowledge in favour of more specialised and purposeful adaptations to the more limited class of situations that the organism or organisms concerned is liable *naturally* to encounter in the course of its life. A human being learns, for example, the language that is spoken in his or her own particular environment, rather than language in general.

These two strategies lead in different directions. The strategy of science leads towards the accurate specification of form, while that of life leads in the direction of meaning. These two directions, form and meaning, are the two components of David Bohm's concept relating to the universal nature of things, *soma-significance*(18). Meaning is an aspect of reality tied to the achievement of goals and to specific context that is sufficiently subtle and complex as not to be representable by any closed formula. Furthermore, the technique of statistical averaging is especially irrelevant in the context of meaning, since its influence in general is to transform the *meaningful* into the *meaningless*. It is not useful to consider the meaning of a particular word averaged over all languages, and computing the statistics of word order and frequency in a discourse tells one very little about the meaning of the discourse. Investigations into meaning(18,19) are investigations in a different direction to that in which one is led by scientific investigations into reproducible form.

But science is involved with the accurate specification of form, and this enforces the kind of *formal* specification of nature characteristic of quantum measurement theory. This contrasts with the philosophical informality of classical physics with its naive realism. The perceptual and interpretative processes of living organisms do not admit of the formal specifications demanded by quantum measurement theory. Therefore, as discussed in Ref. 17, there is no good reason to identify the class of experiments defined according to the precepts of quantum measurement theory with the category of all investigable phenomena. Indeed, the quantum formalism does not apply in any obvious way to *natural* situations, situations such as those of the phenomena of life that come into being by chance rather than by scientific design, and the common belief that it should be possible in some way to apply quantum mechanics to natural situations just as readily as to the controlled experiment is one that seems to owe its existence to an extrapolation that cannot, under close examination, be justified.

6. RANDOMNESS AND FOCUSSING

These arguments lead us to the conclusion that, because of the different kind of perceptual and interpretative processes characteristic of life compared with those of science, living organisms can possess knowledge that is more detailed in certain aspects than is the knowledge specified by the quantum theory. One may talk in terms of higher discrimination and selectivity, which improvements can be attributed a different kind of contact with nature. By way of analogy, it can be compared to a process that makes contact with individual atoms, relative to one that makes contact with the macroscopic aspects of a system only.

From the point of view of a causal model such as that of Bohm's, alternative kinds of probability distribution in phase space become relevant. In general terms, these distributions can be characterised as being highly focussed in relation to the organism's specific goals. Such focussed behaviour in living organisms is typified by, for example, the activities of a tightrope walker, or of a darts player. Efficient focussing comes into being naturally over the course of time as the consequence of processes of trial and error learning occurring during the developmental process. Our assumption in relation to psi functioning is that here also the relevant probability distributions are highly focussed in relation to goals, in a way that may become more effective over time as development through learning takes place.

6.1. An Illustration

The kind of focussing process involved can be illustrated with a simple example. This consists of a coil attached by a length of wire to an ammeter a short distance away. The meter needle can be caused to deflect by moving a magnet in the vicinity of the coil. A person who does not understand the facts of magnetism and attempting to produce a meter deflection in a particular direction will at first move the magnet randomly and hence produce deflections in a random direction. But he may in time discover the principle that is involved and utilise the magnet in a non-random way, and gain thus the ability to produce deflections in a prescribed direction at will. In exemplification of the processes discussed above, his learning process changes an initially random distribution of magnet movements into one focussed with regard to the goal, the principles referred to above. The proposal being made here is essentially that mechanisms of a similar kind may be operative at a *microscopic* level in biosystems.

7. SPECULATIVE MODELS

In the biological world, evolution through natural selection tends to give rise to adaptive elaborations of preexisting phenotypes (manifest behaviour). Thus a primitive sensitivity to light becomes elaborated into more discriminating sensitivities and ultimately into fully detailed vision. In the case of psi one may similarly anticipate the development of forms of organisation of the nervous system capable of interacting non-locally with other systems. Such organisation has been discussed by C.N. Villars(20), who starts with the assumption that in a number of types of situation encountered in a quantum mechanical context, including EPR-type situations, microphysical objects function as "centres of perception", acting as if sensitive to non-local information. Villars hypothesises that somewhere within the nervous system forms of organisation of microphysical objects exist capable of amplifying, selecting and combining the perceptions through non-local connections of individual microphysical objects, in a way analogous to the way in which the ordinary senses function through the working together of many subunits. As a result we can have perceptions of distant objects and events through the non-local connections in the same kind of way as we acquire perception of the more local environment through the ordinary senses. The scope and form of such perceptions at a distance would be a function of the particular forms of organisation and activity present in these postulated sense-like processes. Except for the absence of a theoretical mechanism for overcoming the limitations of ordinary quantum descriptions by making use of an underlying causal model, Villars' proposals are similar to those advocated here.

Further similar proposals have been made by Bohm(21) also, based on his causal interpretation. His conclusion is that while, in principle, coherent non-local effects of one system upon another are possible, in practice such connections are "fragile, and easily broken by almost any disturbance or perturbation", and that they would occur only at very low temperatures or under special conditions such as those pertaining in the EPR situation. But in the picture advocated here, life has the ability, exemplified by the example of the tightrope walker, to learn under conditions that are not excessively unfavourable to it to neutralise of compensate for the effects of external disturbances. Such compensation capacity we assume to be functionally effective in respect to the "fragility" referred to by Bohm also.

A comment by Bohm et al.(9) regarding the understanding of superconductivity in the causal interpretation provides a clue as to what kind of overall organisation might be relevant for psi functioning. This situation is described in the following terms:

> *In the superconducting state of a many-electron system, there is a stable overall organised behaviour, in which the movements are coordinated by the quantum potential so that the individual electrons are not scattered by obstacles. One can say indeed that in such a state, the quantum potential brings about a coordinated movement which can be thought of as resembling a 'ballet dance'.*

The assumption of a superconducting-like state provides an example of a context where different organisms can be highly correlated. Such a state may be relevant to the origin of life, or to the Gaia hypothesis of Lovelock and Margulis(22). Perturbations such as an increase in temperature cause the coordinated organisation to break up, and this would provide a mechanism by which the amount of linking of an individual organism to other systems through non-local interconnections could be adjustable. One may imagine that life may exist from the beginning (cf. Ref. 22) as a cooperative whole directly interconnected at a distance by Bell type non-local interactions, following which modifications through the course of evolution cause organisms to be interconnected directly with each other and with objects to an extent that is adapted to circumstances. One can see conceptual similarities between psi skills and ordinary skills, e.g. between the perceptual skills of hearing and telepathy on the one hand, and between the forms of control of matter involved in the control of the body and in psychokinesis on the other. From this point of view, it is only in regard to the mode of interaction that the ordinary phenomena and the analogous paranormal ones differ from each other. These analogies will be discussed in more detail elsewhere.

The theories discussed here have the feature, in contrast to that of quantum mechanics, of being qualitative rather than quantitative. This may be an unavoidable correlate of such aspects of nature, stemming from a fundamental irreproducibility of biology and of the phenomena connected with the indeterminism of the quantum domain.

8. SUMMARY AND CONCLUDING REMARKS

The goal of this paper has been that of gaining some understanding, within the framework of conventional science, of phenomena such as telepathy and psychokinesis which (particularly in terms of the actual experience(23,24)) seem to involve some form of direct contact at a distance. While the non-local correlations found in EPR-type systems seem at first sight(20) to provide a scientifically valid basis for such direct contact (particularly for the case of telepathy which has many features that parallel those of EPR-type correlations), calculations using the formal apparatus of quantum theory suggest that any such connections will be purely random and thus unusable. But the self-consistent and completely logical multiple-description view of knowledge advocated here, an alternative to the conventional view that all knowledge may be reduced to quantum mechanical knowledge, allows life to have its own potentialities, beyond what the constraints of "good scientific method" will allow, for knowing and for acting on the basis of such knowing. Included in these categories of acting and knowing are psychic functioning.

The present theory parallels in a number of respects the theory of Walker(12) with its postulate that the statistical outcomes of quantum phenomena can be modified by consciousness, and the paper of Stapp(25), in which creative mind has a similar function. These different approaches may all be representations of slightly different aspects of the same underlying truth, gained by taking as a starting point a range of different points of view.

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FOOTNOTES

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4. all references authored by J.S. Bell are reprinted in Ref. 3.
5. The opinion of the authors regarding such phenomena is that in the long run they will be accepted by science and confirmed by it. Arguments in support of this belief fall outside the scope of this paper.

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