# Process and the Implicate Order: their relevance to Quantum Theory and Mind.

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**Abstract**

We present a general discussion of how quantum theory may help to bring about a deeper understanding of the mind/matter relationship. We then examine the particular features of Bohm's ontological interpretation which makes this closer relationship possible. A consequence of all this is that the distinction between mind and matter is further erroded, opening up the possibility of a unified theory containing both mind and matter. This more general theory is discussed in terms of the implicate and explicate orders. The consequences for mind and the self are briefly discussed.

## 1 Introduction

One of the most important questions in the mind/matter relationship is whether mental aspects can be explained in terms of physical properties of the brain. Many philosophers have argued against such a possibility. For example, Brentano and Husserl have concluded that intentionality (which has to do with the directedness of mental states towards other beings or things and more generally the meaning relation) cannot be reduced to a physical property. Metzinger (1995a) describes "Brentano's problem" as follows:

> Many mental states possess intentional content. They are directed to a part of the world and contain it in a mysterious sense

> ('mental inexistence'). It is not easy to explain how this meaningfulness or referentiality of mental states could be grounded in relations in the physical world.

This raises the question as to whether we must necessarily have some sort of fundamental dualism in our world view. The difficulties with such a view are well known and one of the most important aims of contemporary analytical philosophers of mind is to understand how this dualism can be overcome by introducing some form of materialism. Thus it is not surprising that they have tried to accommodate intentionality and meaning within a naturalistic framework. This project is known as "naturalising intentionality" (e.g. Fodor 1990).

Part of this programme involves identifying psychological features with specific physical processes occurring in the brain. These physical processes can be treated in two distinct ways. There are those who argue that there is no need to call on quantum mechanics or any other "exotic" physics in order to make progress and those who feel that it is essential to introduce some aspects of quantum theory or even "new" physics in order to capture the essential features of the relationship between mind and matter. Indeed, as Stapp (1993) has argued that without the quantum side, it will not be possible to make a satisfactory and coherent theory.

On the other hand, Edelman (1992), for example, argues that

> While admitting that the laws of physics apply to both intentional and non-intentional systems, this position (theory of neuronal group election) at the same time denies that fancy physics–such as quantum gravity or other specialised concepts of fundamental physics–are required to explain mind.

Edelman adopts a position of qualified realism and what he calls a *biologically based epistemology.* Within this view there is no Cartesian certainty–knowledge must remain fragmentary and corrigible.

In contrast Stapp (1995) argues that classical physics arises from specific considerations that require us to exclude completely the subjective element from science. It assumes that a reality exists independently of the human observer and his conscious states, and that nature can be described in a way that is independent of any human observer. In other words all observers are assumed to be non-participatory and where interaction with the world is necessary, it can be made as small as one pleases (or at least it can be allowed for by adding suitable correction factors to the experimental results). Since the basic assumption is to banish consciousness in the first place, the attempt to explain the appearance of consciousness as an emergent phenomena necessarily leads to contradictions and forces the appearance of a homunculus lurking somewhere in the shadows of the brain. But, as we have discussed above, the appearance of this dualism lies at the heart of the programme to naturalise intentionality and therefore the use of classical physics is not appropriate.

On the other hand if we turn to quantum mechanics, the observer seems to be playing a key role. As Bohr (1961) has repeatedly pointed out, the indivisibility of the quantum of action means that it is no longer possible to make a sharp separation between the observer and the observed and because of this, the observer seems to be involved in the description of events in a very basic way. In fact in most accepted forms of quantum mechanics, the observer is kept centre stage. In the conventional interpretation the basic variables are *observables*. All that we can describe are relationships between successive observations and no attempt is made to describe what is happening between such observations. This is not merely a form of logical positivism, it goes much deeper. For example Dyson (1979) writes:

> I cannot help thinking that our awareness of our own brains has something to do with the process of "observation" in atomic physics. That is to say, I think our consciousness is not a passive epiphenomenon carried along by the chemical events in our brains, but is an active agent forcing the molecular complexes to make choices between one quantum state and another. In other words, mind is already inherent in every electron, and the processes of human consciousness differ only in degree but not in kind from the processes of choice between quantum states which we call "chance" when made by electrons.

Even if one tries to develop ontological theories of quantum phenomena such as those proposed by Bohm (1952) which is specifically designed to account for what happens between measurements, we find the observer still plays an active but subtle role, a role that is different from the role played in classical physics. The observer becomes a participator by proxy through his instruments. Even in the Bohm approach it is not possible to provide a unique and total individual view of the world that is independent of how the observer attempts to view the world. What the Bohm interpretation shows is that it is always possible to provide an *ensemble* of views (i.e., an ensemble of individual trajectories), each view being contingent on uncontrollable initial conditions. Any attempt to reduce the number of members of the ensemble fails and merely changes the very nature of the ensemble in an irreducible way producing another, different ensemble with an equal number of members. Thus although we can produce an ensemble of possible views consisting of actual well defined individual views, we have no way of defining a single world unambiguously.

There is another important feature of the Bohm ontological interpretation that could be significant to the wider philosophical issues discussed in this paper. It seem worth considering whether the suggested notion of *active information* introduced by Bohm and Hiley (1993) at the quantum level is relevant to the project of naturalising intentionality. Does active information at the quantum level possess some elementary kind of referentiality or meaningfulness to the electron? If this could be made plausible as suggested by Dyson (1979), one could then further postulate that some primitive sort of intentionality is a fundamental property of the universe, perhaps as fundamental as the more usual physical properties such as mass, charge and spin (cf. Fodor 1987); something similar has been proposed about information by Chalmers 1996; for further discussion see Pylkkänen 1992,1995).

Returning to the original proposals by Bohm in his 1952 paper, it should be realised that this work was only meant to be but a stepping stone towards a more radical approach to quantum processes. It was merely the first attempt to show that an ontological interpretation was possible and Bohm himself never saw this as an interpretation that would replace the standard approach. The reason why we wrote the "Undivided Universe"(Bohm and Hiley 1993) was not only to show the logical coherence of the approach but also to open up the possibilities for more radical and, perhaps, more physically compelling approaches. These possibilities had origins in the structure suggested by the formalism used in the Bohm approach but pointed to more radical approaches that needed an overarching philosophy within which these possibilities could form a coherent whole. Bohm felt this could be provided by generalising the notion of order.

We always strongly felt the limitations of the mechanical order which had it roots in the order supplied eloquently by Descartes. We felt the order must be generalised to include a notion of wholeness that seemed so apparent in the details of the Bohm approach, a feature that seems to have been missed or ignored by many supporters of the approach. Furthermore this view suggested a much more organic approach with striking similarities to Whitehead's *organic mechanism.* It was these general features that led

Bohm to develop the notions of the implicate, explicate and the generative orders (Bohm 1965, 1980, Bohm and Peat 1987.) These he felt would overcome one of the central problems of quantum theory, namely, the removal of the sharp distinction between the observer and the observed and ultimately address the even sharper distinction between mind and matter.

The underlying notion basic to this approach is that of activity, or as we put it, of movement, for which we coined the special word the *holomovement* (see Bohm, Hiley and Stuart 1970 and Hiley 1991). Here movement is not to be thought of as a movement of things. There are no things. Rather things, such as particles, objects, and indeed subjects, are regarded as semi-autonomous quasi-local features of this underlying activity. This view is to be extended down not only to atoms but to their basic constituents, electrons, neutrons, protons and even down to the level of quarks.

Thus objects take their form from the totality through a quasi-stable *inner* movement and can only be regarded as 'independent' objects at some approximate level, depending upon their stability. For example, *one* such criterion could arise when the action function is much greater than Planck's constant. Thus the classical level emerges in processes where Planck's constant of action can be neglected.

Where it cannot be neglected, we have quantum phenomena. We see this quite clearly in quantum entangled states where some of the properties of the individual 'particles' are not well-defined. This feature was already recognised by Bohr who regarded it as an essential ambiguity at the heart of nature. But care must be taken not to assume that these quantum effects only appear at microscopic dimensions and cannot have relevance to mind. The stability of matter, a desk for example, owes its rigidity to quantum processes. The distribution of the radiation from the sun is determined by quantum processes. Thus quantum processes can and do determine macroscopic behaviour.

But to return to entangled states. Here we find that the properties of the whole condition the properties of the individual even to the extent that these properties appear ambiguous. For example if a pair of spin-half particles form a singlet spin-zero state, no definite state can be attributed to the components of the spin of the individual particles. This is unlike anything we see in the classical world. There the properties of the individual are always sharp and necessarily determine the properties of the collection. In quantum mechanics it is the other way round. Systems form *wholes* or better still *totalities* where the whole is not the sum of the separate parts. The whole gives form to the parts, it organises the parts so one can say there is a kind of organic process involved. Here we are using the term *organic* in the sense of Whitehead (1938). In other words the holomovement is a basis for an approach which we could term, following Whitehead, *organic realism*.

It is important to realise that when we use the term 'holomovement' we are not just referring to objects moving through space. We are referring to much more subtle orders of change, development and evolution of every kind. Bohm (1976) illustrates this generality by referring to the movement of a symphony. Here there are the individual notes which are carried by oscillating air molecules but the movement of the symphony cannot be understood by the motion of the air molecules. Here the term *movement* is referring to something much more abstract, but nevertheless it is real, carrying meaning for our emotions. It is clear that the movement of a symphony involves a total ordering, where the past and future actively intermingle, creating an order which transcends the temporal order of the notes. Thus one can apprehend the whole symphony at any moment.

It is not merely in music that we see the generality of the notion of movement. Take life for example. Here we have another form of movement in which all the various functions of the life form are organised to work together to create and maintain the whole organism. Whitehead (1938) draws our attention to this feature when he writes

> An electron within a living body is different from an electron outside it, by reason of the plan of the body.

We can think of life as an organising energy that is working from within through the movements of its organs, its cells and indeed every molecule and atom, ultimately merging with the universal field of movement, the holomovement.

This movement clearly goes beyond the motions of the individual atoms and molecules. These motions are merely the explicate orders that science has excelled at untangling and describing. What has not been appreciated is the deeper implicate order, the order that lies behind the entangled states of quantum mechanics, that lies behind the symphony and, indeed, behind life itself. It is the overarching order that organises the parts, not through external forces but through new organising principles that are only just beginning to be articulated.

As we have brought out briefly above we see some striking similarities between the ideas underlying the implicate order and the ideas contained in Whitehead's notion of organic mechanism. There are also some striking differences. Whiteheadians emphasise the fundamental role played by the notion of ‘process’. We feel that our use of the word ‘movement’ is more appropriate for the subtle orders we want to include in science. The word process cannot be used, for example, in the context of a symphony. It is clearly inappropriate to talk about the *process* of a symphony. The word ‘to proceed’ means literally ‘to step forward’ thus refers to a special kind of movement where one step follows another. The movement of a symphony, however, involves a total ordering which involves the whole movement, past and anticipated, at any one moment.

In spite of this difference, the two approaches have a basic similarity in the way they treat of the subject/object division. The way Whitehead puts it

> the philosophy of organism is the inversion of Kant’s philosophy For Kant, the world emerges from the subject; for the philosophy of organism, the subject emerges from the world.

Indeed we will bring out some of these similarities when we discuss the mind/matter relationship. For many researchers the debate about intentionality has to do with mental, as opposed to physical properties, but does not yet necessarily bring conscious experience into the picture. But it is today more and more widely recognised and admitted that the truly difficult problem in cognitive science and philosophy of mind is how to accommodate not only intentionality as a non-conscious mental feature, but also conscious awareness in the physical world. In other words how can we reconcile experience with the world that is experienced?

## 2 Unity of consciousness

There are a number of features of consciousness currently debated by philosophers and cognitive scientists, and we will here briefly consider only some for which quantum mechanics might be relevant. One of these is the unity of consciousness, described by Metzinger (1995) as follows:

> ...the classic problem of the unity of consciousness - in the sense of a synthesis combining the different contents of consciousness into a holistic entity - appears in the contemporary philosophical discussion as the question of the integration of phenomenal content and in the empirical sciences as the binding problem. Our field of consciousness has an undeniable holistic

> quality. The different forms of phenomenal content that are active in its stand in part-whole relationships to this field. This holism is a higher-order property of consciousness ... The unity of consciousness is a highest-order property of the phenomenal model of reality active at a certain time. This global unity of consciousness seems to be the most general phenomenological characteristic of conscious experience, and is therefore difficult to understand on a conceptual level.

Although one is here talking at a very general and admittedly vague level, anyone who has a familiarity with quantum mechanics knows that a certain non-classical kind of wholeness or unity is a crucial feature of quantum phenomena. Just as with the unity of consciousness, this wholeness is difficult to conceptualise. This is not the case in the Bohm approach where the wholeness emerges in a very precise way, namely, as *nonlocality.* Unfortunately it gives the impression that it can be regarded as a mechanical feature rather than a more subtle feature that would be more appropriate for mind

Almost ever since quantum theory was first proposed there have been suggestions that these two kinds of wholeness might be related to each other. For example, it has been suggested that perhaps there is some kind of quantum wholeness (or something at a higher level but analogous to quantum wholeness) that is present in the neural processes associated with consciousness.

This is a feature recognised by Whitehead (1957). His notion of organic mechanism abandons all sharp distinctions between subject-predicate forms. An actual entity is at once the experiencing subject and the superject of its experiences. Thus it is subject-superject as an whole entity in which neither half of the description should be lost from sight. The problem is how we can accommodate such notions into our physics.

We have already pointed out that this kind of unity seems to be incompatible with the separability that appears to dominate the domain of classical physics, including the separability of the neural processes in the brain, as these are understood today. It thus seems hard to reconcile the undivided wholeness of our experience with the apparent separability of objects in the physical world. If one wants to find a physiological concomitant of this unity one is searching for some sort place or process in the brain which combines information to form a whole. Edelman (1992) claims that this can be done by introducing the notion of re-entrant connections. It is not clear that this will work and we should, instead, be looking for some qualitatively new feture of wholeness in the physiology of the brain. Thus, for example, the time synchronisation provided by the well known 40 Hz oscillation does not necessarily qualify as an explanation of the unity of consciousness insofar as it relies on essentially classical notions which presuppose separability.

Here is a very specific area where the quantum theory might help, as already hinted above. For the quantum theory implies that the physical world, too, is radically holistic in a sense that is absent in the classical everyday domain. If, say, brain processes involve quantum holistic effects in some way, it seems reasonable to at least consider the possibility that these effects are related to the unity of consciousness. Here one need not be trying to reduce consciousness to a quantum mechanical neural process. One can rather try to find a plausible neural correlate or concomitant for conscious experience.

There are other difficult aspects of the consciousness/mind/matter relation that deserve a brief mention here. There is the problem of experience vs. objective physical process. Why should an objective physical process, such as a neurophysiological process, give rise to or be accompanied by experience at all? This is what Chalmers (1996) calls the "hard problem of consciousness". There are at least two different ways in which one could approach the hard problem in light of the quantum theory, via the suggestion of active information and Bohm's (1980) deeper suggestions involving the implicate order.

It is interesting to note that Chalmers (1996) himself has approached the hard problem by first postulating that information is a fundamental property of the universe and then by further suggesting that information has two aspects, the physical and the phenomenal. By saying, in effect, that something phenomenal is fundamental in the universe, he hopes to make the appearance of conscious experience with physical processes more intelligible. In this regard the ontological interpretation provides a very concrete example of how information plays a fundamental role in physical processes, perhaps more so than Chalmers' discussion has been able to establish so far. If we now interpret active information in the spirit of Chalmers by assuming that it has both a phenomenal and a physical aspect, we have a concept of information which is both concrete and fundamental and also may help to approach the hard problem of consciousness in a more satisfactory way.[1]

[1]This discussion is very tentative and general indeed. Most importantly one needs to note that Chalmers uses a Shannon-type notion of information which is different from

Before concluding this section it is worth noting that in the history of Western philosophy at least since Berkeley and Hume it has by no means always been taken for granted that mind and consciousness should be explained in terms of matter.[2] On the contrary, for many philosophers the existence of a mind-independent physical world has been the central problem of philosophy and some have opted towards antirealism, by questioning the idea that the existence of reality is independent of the human mind. But because of the current prevalence of common sense physicalism especially in the Anglo-American cognitive science and analytical philosophy community, the antirealist direction is largely ignored and the problem of consciousness tends to be the problem of explaining how consciousness arises from the physical world and how it is related to it. However, the lack of progress in this issue is beginning to alert researchers to the possibility that some form of antirealism is also a possibility when trying to understand human experience in a naturalistic fashion (see Varela (1991); Globus (1995); Pylkkö (1995)).

This, very simply and briefly, is the background. Active information at the quantum level may help in understanding the place of meaning in the world, and similarly quantum wholeness, particularly as articulated in the more general notion of the implicate order, promises to make the unity of consciousness easier to accommodate in a naturalistic framework. Active information may further make room for the idea that nature can have a phenomenal aspect at a very general level. Information and phenomenal experience can be seen as fundamental features of the world instead of being secondary, emergent properties, which provides us with an alternative way of approaching the hard problem of consciousness.

## 3 The Bohm interpretation

In order to provide the necessary background for our discussions it is usefull to briefly outline of the relevant features of the Bohm interpretation. (For more details see Bohm and Hiley 1993). At first sight the starting point for the Bohm interpretation seems very unlikely to lead to anything remotely connected with mind. Its original purpose was to banish the observer from

Bohm's notion of active information. The implications of this difference need to be worked out in detail.

[2] Of course, even Descartes, let alone many of the Greek philosophers, as dualists, did not try to explain mind in terms of matter.

the description of quantum phenomena. To this end we first substitute the expression $\psi(\boldsymbol{r},t) = R(\boldsymbol{r},t)\exp[iS(\boldsymbol{r},t)/\hbar]$ into the Schrödinger equation and then separating the real and imaginary parts of the resulting equation, we find that the real part gives

$$\frac{\partial S}{\partial t} + \frac{1}{2m}\nabla S^2 + V + Q = 0. \tag{1}$$

This equation would be identical to the single particle Hamilton-Jacobi equation provided $Q = 0$. In such a theory each particle has well defined position and momentum. But $Q$ is a quantum mechanical term and takes the form

$$Q = -\frac{\hbar^2}{2m}\frac{\nabla^2 R}{R} \tag{2}$$

It is this term which produces a behaviour in the particle that distinguishes it from a classical particle. For those unfamiliar with the Hamilton-Jacobi theory will more easily recognise the following formula:

$$\frac{d\boldsymbol{p}}{dt} = -\nabla[V + Q], \tag{3}$$

which is just Newton's equation of motion with an additional potential, $Q$, which known as the quantum potential.

Now it is well known that Newton's equation produces particle trajectories in the classical case as does the Hamilton-Jacobi equation. We argue that when $Q$ is very small, but not zero, it is still possible to calculate trajectories from equation (3) and that these trajectories will hardly differ from the classical trajectories. As $Q$ slowly increases, the trajectories will differ more and more from the classical trajectories, but at no point will we be able to say "At this point we must give up the notion of a trajectory". This implies that even in the quantum domain we can still regard every particle as having a well-defined position and momentum but in order to produce the quantum behaviour it must be accompanied by a new field $\psi(\mathbf{r},t)$ which satisfies the Schrödinger equation. Indeed these quantum trajectories can be (and have been) calculated for many different situations, including the classic two-slit interference experiment (see Bohm and Hiley 1993 for more details).

Quantum mechanics uses probability and in the Bohm approach the connection with probability emerges from the imaginary part of the Schrödinger equation. This is written as

$$\frac{\partial P}{\partial t} + \nabla(P^2 \frac{\nabla S}{m}) = 0. \tag{4}$$

Here $P(\boldsymbol{r}, t) = R(\boldsymbol{r}, t)^2$ is interpreted as the probability of the particle to be at a particular point, $\boldsymbol{r}$, at time $t$. The statistics then arises simply from the contingent initial positions of the particle.

## 4 The properties implied by the quantum potential

It appears on the surface as if we have found a way to describe quantum phenomena in terms of classical concepts, and that we have surprisingly retained determinism. To achieve this all we seem to have done is to rewrite the Schrödinger equation in a form that *reveals* a new potential [3], but if we probe deeper, we find that this new potential is totally different from any classical potential that has been used to date. This point is often missed by some supporters of this approach. This is because the potential appears alongside the classical potential in equation (3) and it looks as if an additional classical potential has been added to Newton's equation of motion. However the potential is derived from the quantum field $\psi(\boldsymbol{r}, t)$ and it is from the properties of this field that the differences arise.

One feature that is of particular importance is that, unlike potentials derived from classical waves, the quantum potential is independent of the amplitude of the quantum wave. This means that a wave of very small amplitude can on certain occasions produce a large effect on the particle. In fact the force ultimately depends on the form of the wave profile.

We can give a useful analogy by recalling that in radio transmission the audio signal modulates the profile of the high frequency carrier wave. Here the audio energy can be quite small, but its form can be amplified to produce a large effect in the radio itself. By analogy the small energy in the quantum wave can be magnified by some as yet unknown internal process so as to produce a large effect on the particle. Thus there is an internal process that is ultimately responsible for the quantum behaviour.

When we apply these principles to the case of a single particle, the energy to produce these changes must come from within the particle itself as there is no external source to provide the necessary energy. To see how

[3]It must be emphasised that this potential in *not added* from outside. It is already present in the real part of the Schrödinger equation.

this comes about, let us consider a stationary state for simplicity. Here the single particle Hamilton-Jacobi equation can be written in the form :-

Kinetic energy + classical PE + quantum PE = total energy.

where PE stands for potential energy. Since the total energy is fixed, any change in the motion of the particle comes from a re-distribution of energy between the various kinds of energy. This redistribution can be regarded as a kind of self-organisation involved in the whole process.

The form dependence also helps us to understand why the quantum potential can produce significant effects over large distances. As a wave spreads out over a greater and greater distance, the amplitude of the wave decreases and any energy in the wave becomes more spread out. Had the force depended on the amplitude, then the force would necessarily decrease with distance, but since the quantum potential does not depend on the amplitude, the resultant force is not constrained in this way. Thus it is possible to have very long range quantum forces and even non-local forces of the type required to account for the situation described by Einstein-Podolsky-Rosen (1935) paradox.

We can take these arguments one stage further. If we consider the quantum potential in particular cases, for example, in the two-slit experiment, a detailed examination of the mathematical form of the quantum potential shows that it contains information about the momentum of the particle, the width of the slits and how far they are apart. That is, the potential carries information of the whole experimental arrangement. We can regard this information as being active in the sense that it modifies the behaviour of the particle. Bohr (1961a) came to a similar conclusion, but from a very different point of view. He saw the necessity of talking about the *wholeness of the quantum phenomena*. He writes:

> As a more appropriate way of expression I advocate the application of the word *phenomenon* exclusively to refer to the observations obtained under specified circumstances, including the *whole experimental arrangement*.

For Bohr *wholeness* implied that the quantum process could not be analysed even in principle, but the Bohm interpretation shows that analysis is possible and by carrying out this analysis, we can provide another way of understanding what is meant by *quantum wholeness*, a point we will discuss later.

It was this type of consideration that led us to the suggestion that the quantum potential should be considered as an *information potential.* Not only does the quantum potential carry information about the experimental set up, but, more importantly, it induces a change of *form from within the system itself.* It is in this more general sense that we can regard the quantum potential as an information potential. In making this suggestion, we were strongly influenced by the etymological roots of the word 'information'. In its simplest form to in-form literally means to form from within. As Miller (1987) writes:

> As with many words in the English language, the word "information" has both Greek and Latin roots. The Latin informatio bears direct and obvious structural similarities to our modern "information". The prefix (in) is equivalent to the English "in", "within", or "into"; the suffix (ito) denotes action or process and is used to construct nouns of action. The central stem (forma) carries the primary meaning of visible form, outward appearance, shape or outline. So informo (or informare) signifies the action of forming, fashioning or bringing a certain shape or order into something, and informatio is the noun from which signifies the "formation" thus arrived at.

In other words this information can be either active or passive.

The information carried by the quantum field is clearly not information for us, it is information for the particle and as such is objective. This information has meaning for the particle. Since meaning is involved, we are not using the word "information" in the sense of Shannon (1948). According to Shannon, the information content for the word "coming" as calculated using the expression $H = \sum p_i \ln p_i$ is exactly the same as the word "gnmioc", but one is meaningful and the other is not. The quantum potential always has meaning for its particle, although it might not have meaning for other particles at the same location as can be seen in the next example.

To bring this out we need to consider groups of particles. Consider, for example, a situation in which we have two sets of particles, A and B. Suppose system A is described by a non-product, or "entangled" wave function $\Psi_A(\boldsymbol{r}_1, \boldsymbol{r}_2, .....\boldsymbol{r}_n, t)$ which will produce a quantum potential $Q_A(\boldsymbol{r}_1, \boldsymbol{r}_2, .....\boldsymbol{r}_n, t)$ that couples all the particles of A into a coherent group, while the B group of particles are linked by a different quantum potential $Q_B(\boldsymbol{r}'_1, \boldsymbol{r}'_2, ....\boldsymbol{r}'_n, t)$ which arises from a different non-product wave function$\Psi_B(r'_1, \boldsymbol{r}'_2, ....\boldsymbol{r}'_n, t)$. This implies that we have two independent groups of particles, each group being co-ordinated into some kind of coherent unit where each particle of the group responds *only* to the co-ordinated movement of the rest of the particles in its own group.

To help understand this co-ordinated movement we have likened the group behaviour to ballet dancers whose movements are co-ordinated, not by direct mechanical forces, but rather by each individual responding to a common theme. In the case of the ballet each dancer responds to the *meaning* provided by the musical score as it develops in time. Thus in the analogy the wave function provides the "score" to which the particles respond. The two independent wave functions correspond in the analogy to two sets of dancers following their own theme. Here the form of the movement in each group can be regarded as unfolding from within and the energy that is needed to bring about these changes is provided by the individuals themselves. Although the analogy has obvious weaknesses, it nevertheless highlights the radical difference between classical forces and the type of effect generated by the quantum potential.

One can see why attempts to continue to regard the quantum potential as producing another kind of mechanical force will fail by considering the two sets of particles discussed above. Members of the two groups can be in the same region of space and provided they have no classical forces between them, they will not experience the quantum potential of the other group. The quantum potential for each group is somehow a 'private' experience for only that group. In other words not only can this information be 'active', it can also be 'passive'. The information of group $B$ is passive as far as the behaviour of group $A$ particles are concerned and vice versa. There is no mechanical way, say, by supposing a single sub-quantum medium to bringing about such behaviour.

Since the group behaviour is something that is intrinsic to that particular group of particles and to no others, it seems, once again, as if there were some kind of self-organisation is involved, but a self-organisation that is shaped by the environment and mediated by the quantum potential. Thus the system behaves as a *whole* or a *totality* in such a way that the particles appear to be nonlocally linked.

This radical approach suggests that nature at its very fundamental level is more *organic* than expected and as we have already pointed out, this view was shared by Whitehead. Indeed Bohm (1951) felt that a non-mechanical view is suggested even if quantum theory is looked at from the conventional point of view. In his book *Quantum Theory* he writes:-

> The entire universe must, on a very accurate level, be regarded as a single indivisible unit in which separate parts appear as idealisations permissible only on a classical level of accuracy of description. This means that the view of the world being analogous to a huge machine, the predominant view from the sixteenth to nineteenth centuries, is now shown to be only approximately correct. The underlying structure of matter, however, is not mechanical.

In a footnote he adds:-

> This means that the term *quantum mechanics* is very much a misnomer. It should, perhaps, be called *quantum nonmechanics.*

Our use of the novel concept of *information potential* has, understandably, met with some scepticism. In order to try to counter this we will present some examples in which concepts like active and passive information have immediate use. Furthermore these examples have direct relevance to the mind/brain problem.

The first uses the analogy of the computer. Here information is carried in the chip and all of this information is passive until the appropriate software activates some of the information. Thus when the computer is working, some of this passive information becomes active, modifying the input by giving it new form. Hence in the computer there is a continual interplay between passive and active information. It is interesting to note that Feynman once proposed that every point of space is like a computer processing incoming information and outputting new information (see Finkelstein 1969). For our approach to non-relativistic quantum mechanics, it is the particle that processes the information although in field theory (which we discuss later) our approach is very similar to the kind of structure Feynman had in mind. In the case of the computer, the significance of the information is decided by outside human activity both in terms of the software we use and the type of information that is stored in the chip.

It would be more convincing to have an example where there is no direct human intervention and it is here that the neural net provides a better example. In this case the net learns how to function by receiving information from some external source. Once that information has been stored in the net, it then remains passive until the net is activated. Neural nets do not need quantum mechanics in order to function, being essentially based on the classical Ising model. However this model is itself an approximation to a fully quantum verson known as the Heisenberg model. It seems clear that Heisenberg model will have properties that are different from those of the classical model, but what is not clear is whether these properties will have features that will be of direct relevance to the brain.

We have also used DNA as an analogy. In this case, the genetic code can be regarded as the passive information that has accumulated over the years through the process of evolution. It was not put there by man (although this need no longer be the case.) Parts of this code can be accessed by RNA which carries the information to the appropriate part of the cell where the information can become active in the sense that the processes in the cell change to allow it to develop in a new and meaningful way. Here we see how passive information becomes active under appropriate conditions.

Notice that in all the examples above the additional energy does not necessarily come from the information carrier, but has some other source. In the case of the computer or the neural net, it comes from the battery or external power point. In the case of the cell, it literally comes from within the cell itself.

If we are right in identifying the quantum potential with active information and this active information is of a similar kind operating at the molecular level then this might be of direct significance to the brain, particularly if we follow the view articulated by Edelman (1992). He suggests that the key process going on in the brain is the selection and modification of groups of neurons produced by information entering through external stimuli. These groups then produce an appropriate outward response, which, if successful, will produce a stablising effect on the member of the species responding to the external environment in a sensible way.

## 5 Implications for mind/brain relationship

In the above discussion we can already see some of the concepts emerging from quantum theory have features that may be appropriate to the way we talk about mind. Certainly thoughts are displayed from within and can take on the appearance of permanent entities (or least semi-permanent entities) which are displayed before our intellectual gaze. We could try to liken these aspects of thought to some kind of particle-like features such as the *psychons* suggested by Eccles (1994), or the *corticons* introduced by Stuart, Takahashi and Umezawa (1978), or indeed the *protophenomena* postulated by MacLennan (1996). Some aspects of these thoughts could be regarded as changing in a mechanical way, but there are other more subtle features that could be regarded as being changed in a manner that is analogous to the way the quantum potential operates. For example, the appearance of wholeness in the quantum potential would then provide an alternative account of the binding problem that we mentioned earlier. Here it will be the activity through a quantum potential-like process that provides the link to the common pool of information that unites thoughts into a coherent whole and sustains its unity. It also has the possibilities of giving rise to something that goes beyond the sum of the parts and opens up new domains for exploration that have certain resonances with the ideas of Hegel and Schelling.

One drawback to all this is that the particles appear to be permanent entities, whereas the semi-permanent aspects of thought can easily fade away and even disappear completely! The analogy becomes much more compelling if particles are not thought of as rock-like entities but as quasi-stable excitations of a deeper processes. Such a view is much closer to the way particles are treated in quantum field theory. Indeed the use of fields as basic entities is much more appropriate to the functioning of mind. The notions such as corticons and protophenomena can be considered as collective features of groups of neurons or as excitations of the dendritic fields or the action potentias. In this way we could provide a mathematical basis for Pribram's (1991) *holoscape*. (For a detailed discussion of this approach see Jibu and Yasue (1991)).

## 6 Extension to quantum field theory

In view of the role that fields are expected to play in the discussion of the mind/brain relation, it is important to realise that the Bohm model can easily be extended to fields (For more details see Bohm and Hiley (1993)). The field, $\phi(\boldsymbol{r},t)$, and its conjugate momentum, $\pi(\boldsymbol{r},t)$, replace the position and momentum as beables. These field quantities would then be the appropriate variables that are to be identified with the relevant fields functioning in the brain. These fields would be organised by a generalisation of the wave function, namely, the wave functional of the field, $\Psi(\phi(\boldsymbol{r},t))$, which we call the superwave function. The time evolution of this superwave function is described by a super-Schrödinger wave equation

$$i\frac{\partial\Psi(\phi(\boldsymbol{r},t))}{\partial t} = H(\phi(\boldsymbol{r},t),\pi(\boldsymbol{r},t))\Psi(\phi(\boldsymbol{r},t)), \tag{5}$$

The correspondence between field theory and the particle theory is as follows:-

$$\boldsymbol{r} \longleftrightarrow \phi(\boldsymbol{r},t) \qquad \boldsymbol{p} \longleftrightarrow \pi(\boldsymbol{r},t) \qquad \left(= \frac{\delta L}{\delta \dot{\phi}}\right)$$

$$\psi(\boldsymbol{r},t) \longleftrightarrow \Psi(\phi(\boldsymbol{r},t))$$

$$\frac{\partial S}{\partial t} + \frac{(\nabla S)^2}{2m} + V + Q = 0 \longleftrightarrow \frac{\partial S}{\partial t} + \tfrac{1}{2}\int [(\frac{\delta S}{\delta \phi})^2 + (\nabla \phi)^2] d^3r + SQ = 0$$

$$Q = -\frac{1}{2m}\frac{\nabla^2 R}{R} \longleftrightarrow SQ = -\frac{1}{2}\int \frac{\delta^2 R}{(\delta\phi)^2} d^3r$$

Here we find there is a super-quantum potential, SQ, that organises the field through a Hamilton-Jacobi field equation.

Since these equations have the same form as those describing particles, all the qualitative ideas discussed above for the particle model apply equally to quantum fields. However this provides a much richer structure and is far more appropriate for discussing the mind/brain relationship.

# 7 Beyond the Cartesian Order

Throughout my discussions with David Bohm concerning quantum theory, it seemed as if the differences between mind and matter were being eroded, a fact that he often emphasised. Since particles and fields themselves could be better understood if we regarded them as being influenced by information, what was needed was new categories that will be sensitive to the kind of changes that are necessary to accommodate both matter and mind without having to resort to Cartesian dualism.

However the problem with the Bohm interpretation as it stands is that the fields are regarded as existing in space-time, the space-time manifold being assumed to exist *a priori*. As we have remarked earlier, with such a view one can still makes a destinction between physical processes in space-time, and thought. Thus the Cartesian distinction between *res extensa* and *res cogitans* remains and as long as it is assumed that this distinction is necessary, naturalising intentionality will always remain a problem.

To further appreciate why quantum theory errodes the boundary between thought and non-thought without being forced into the Cartesian dichotomy, it is necessary to be aware of the conceptual difficulties that arise in any attempt to quantise gravity. When any field (such as the electromagnetic field) is quantised, it is subjected to quantum fluctuations. If general relativity is a correct theory of gravity then we know from the theory that the metric of space-time plays the role of the gravitational potential. If the gravitational field fluctuates, the metric must fluctuate. But the metric is intimately related to the geometry of space-time. It enables us to define what is meant by angle, length, curvature, etc. In consequence if the metric fluctuates, all the geometric properties of space-time will also fluctuate. It is not clear to me what it means to have a fluctuating space-time.

Suppose at a deeper level, let us say at a sub-quantum level, space-time has no meaning, but that space-time emerges at some higher, semi-classical level. This could involve some form of statistical averaging in which the nonlocal effects average out to produce the local behaviour required at the classical level. Indeed we have already argued elsewhere (Hiley 1991) that local relations and Lorentz invariance are statistical features and that underlying this is a structure that does not find a natural expression in the space-time continuum. The nonlocal features, which appear also in the standard approach to quantum theory, are then a macroscopic reflection of this deeper structure. In other words, this pre-space is not merely a curiosity manifesting itself at distances of the order of the Planck length ($\sim 10^{-33}$ cm). It has immediate consequences at the macroscopic level giving another possible example of how underlying sub-quantum processes can determine macroscopic behaviour.

The actual nature of this pre-space is still being explored and we are a long way from understanding its essential features. However it gives us the opportunity of escaping the reductionism that traps us in space-time. As we have already stressed, one of the essential features exhibited by quantum processes is a kind of *wholeness* or *nonseparability* which denies reductionism. The inseparability of the observer and the observed goes much deeper. It suggests a new order that requires nonseparability to be built in from the very start. It requires the notion of what we will call 'partial manifestation', as opposed to a unique 'third eye' description required by the Cartesian order. This new view must recognise that participation is a key element of the description. Participation is not merely a disturbance of the system because one is somehow 'ham-fisted', but because the 'disturbance' is actually necessary, fundamental and irreducible, exactly in the manner that Bohr has stressed. There is a kind of wholeness that denies the possibility of having a sharp separation between the observer and the observed system, and it is this wholeness that shows up as nonlocality when analysed in terms of the Cartesian order used in the Bohm approach.

In contrast, the Cartesian order depends upon the notion of absolute locality. In relativity we retain absolute locality even though space and time become relative. Is it possible to introduce a notion of relative locality? In other words, can we develop an order that does not take locality as basic and absolute? If we can do this, we are then forced to look at spacetime in an entirely different way. To add some support to this idea, recall that in quantum mechanics we must either use a spacetime description, or a description that works in the momentum-energy domain. We cannot use both together. In the latter, spacetime itself is not defined. This is just another way of looking at the consequences of the uncertainty principle. It is the essential lesson of Bohr's complementarity, namely, that in quantum mechanics we cannot use both descriptions together as you can in classical physics. This is to be contrasted with the Cartesian order which demands that we take spacetime to be basic and absolute, and all reality must be thought of as going on in space and time while energy and momentum remain sharply defined.

The existence of the hologram has shown how locality can be carried as a relationship. For example in forming a hologram, the neighbourhood relations in an object are mapped into the whole domain of the hologram. If this were not so we would not see an image of the original object when only a partial region of the hologram is illuminated. The significant feature of the hologram is that local regions of the original object are mapped into every region of the hologram. Thus locality is being carried in a nonlocal or, better still, alocal way. In other words, locality can be regarded as a relationship that does not have to be represented locally. This example shows us that locality is not necessarily absolute. Thus we can, in fact, have processes which do not have to be displayed in spacetime, but nevertheless carry the spacetime properties implicitly within their structure, In this way we have the possibility that spacetime could emerge from this deeper process.

These ideas tie in very nicely with the notion of the holomovement that we introduced earlier. Not only are particles to be thought of as stabilities in this movement, but space-time itself is to be an abstraction from the holomovement. This means we must not view the vacuum as 'empty space-time'. It is not empty, but is full of *undifferentiated* activity. The particles are then regarded as being mere 'ripples' or invariant features sitting on top of this holomovement. Electrons are not little rocks, nor are quarks. We must not fall into this trap. Whitehead (1926) has warned us against *the fallacy of misplaced concreteness*! We must regard particles as quasi-stable, semi-autonomous forms on the background activity. They depend on the background movement and are part of the whole process.

So there is no ultimate separate substance, there are only concentrations of energy. Furthermore since all quasi-invariant forms can be seen as being connected through the background activity, we now have a possible way of understanding how nonlocality can arise. The particles are not separate entities in interaction but are distinguished forms arising from a common interconnected background.

In order to give some insight into how 'particles' might appear, Bohm (1980) made use of a rather ingenious device called the unmixing device. This consists of two concentric cylinders with some glycerine between them (the glycerine and the cylinders are transparent). Suppose we put a spot of dye in the glycerine and then turn the outer cylinder relative to the inner. After $n$ turns the spot disappears and no trace of it is evident. But when the cylinder is rewound, lo and behold the spot reappears! It looks as if what has disappeared actually returns and the glycerine contains, in some sense, a memory of the order of the past.

Suppose now a series of dots are put into the glycerine at different points. First we put one in at one point and turn the cylinder. Then put another spot in at another point and turn the inner cylinder again, and so on. If the sequence is run backwards, the spots will reappear and then disappear again, one spot following another. On seeing this sequence of dots, one may be tempted to infer that something had crossed your line of vision, but actually nothing of the kind has taken place. No particle actually crosses the screen. Rather there is a continuing process of condensing, evaporating, re-condensing, re-evaporating, and so on[4] (See Bohm 1986 and Hiley 1994). Or in Bohm's words, there is a continual unfolding and enfolding of orders. The proposal, then, is that this may provide a richer picture of quantum processes. There is no continuity of substance, merely an unfolding of form. The more stable the form, the more persistent it is.

Suppose we apply this idea to the two-slit experiment, the slits will see this unfolding process and it will look as if a wave has gone through both slits, but the total process will manifest itself only when the energy is condensed to a small region, giving the appearance of a particle. There is no continuing particle, no continuity of substance, merely a continuity of form. Notice the order need not always be manifest. We also have a non-manifest reality which implicitly contains the order. To make a feature manifest

[4]It was not our intention to imply that there exists a sub-quantum medium composed of yet smaller 'particles' that carried the 'dye'. Rather this unfolding and enfolding was a fundamental movement that could be described by elements of an algebra.

we need a special physical process which we call observing instrument. The total process of the manifest and the non-manifest is a new order that Bohm (1980) called the *implicate* order.

## 8 The implicate order

It is now clear that a key features of this new order is that everything cannot be made manifest together and it is this feature that destroys the "Cartesian theatre" (see Dennett (1991)) in which it is assumed that everything can be made manifest together, all at the same time and displayed before us.

To emphasise this feature let us consider the glycerine metaphor again. Consider two of the dots enfolded into the glycerine. As one spot appears, the other is still enfolded and will not appear until the inner cylinder is further rotated during which time the first spot is enfolded again. Further enfoldment makes it disappear as well. In other words, the reality that is made manifest contains deeper orders implicitly, even though only certain aspects of an order can be made manifest at any one time. It is these deeper orders that are called the implicate order. What can be made manifest together is called an *explicate* order which is only a partial order at the level of manifestation. But there may be many different explicate orders, each one giving rise to a unique appearance. Our participatory role as observers is then to make one particular order manifest or explicate, rather than another. It is only in the classical domain that participation can be neglected so that the whole classical order can be contained in one unique explicate order.

The new paradigm based on the implicate order, if correct, has deep implications for nature in general and offers the possibility of including a wider domain of phenomena. For example, in biological systems the notion of the unfolding form plays a central role and if non-biological systems also need to be described in terms of unfolding forms, then we have removed one distinction between organic and inorganic systems.

Furthermore the implicate order also seems to offer a way to encompass our thought processes. For example, if you try to hold an idea in the 'working store' of your mind and attempt to keep it there, you know what inevitably happens, it disappears back into the general process of thought. Indeed in the mind, thought structures are continually appearing and dissolving. However there are relatively stable forms which can be re-captured easily and these are called 'memories'. But we know that on a longer time scale memories fade and become modified.

There is some similarity with ordinary matter to which we have already referred, namely, that particles are quasi-stable forms in an underlying process. One essential difference is that familiar matter is far more stable. It should not be forgotten however that some elementary particles decay within $10^{-24}$ seconds after being created! In large scale matter, the stability is, of course, much stronger still, but even mountains move! This principle of stability is very important because without it, there would be no classical world. Thus as the particles begin to form out of the cosmic primordial Big Bang, the seeds of the classical world are sown and this world begins to dominate as more structures form and stabilise. But underlying these explicate features of matter and mind is the deeper order, namely, the implicate order.

## 9 The new order and mind

As we have seen, the general structure of this new order has given us the possibility of a new way of understanding material process, not as mere mechanism, but as some form of organic structure. In trying to articulate the dynamics of this type of structure we use descriptive forms that are closer to the way we try to discuss thought. For example, thought is about the organisation of form and structure. It is certainly not about ordering material substance. We lift thought into immediate attention and hold the thought as a quasi-stable structure which we can reflect on, forming a temporary Cartesian theatre. In this process it is as if thought polarises into two distinct aspects. There is what can be made manifest, and there is the process that is producing the manifestation. These two aspects actually form one totality, but one aspect is unfolded in the relative stability of the other. One can regard the process that produces the manifestation is what we identify as self. Thus the self is built on the more stable structures that have been laid down in the brain or in the neural nets by the type of processes envisiaged by Edelman (1992). These are relative stabilities built into the neuron structures. They are not permamnent, they can change but it can require a lot of energy to restructure them. It must be remembered that those features that constitute the manfestation are unstable and as we know too well can easily sink into the background and requires effort to re-create them. But in thought this lack of stability is not conceived as a problem as it is when we consider "particles" as being quasi-stable forms on a background of process.

Furthermore to organise any thought process we need information. We need to give form to our thought and we do that using information stored in memories or new information coming in from outside. This information does not seem to be located in any specific area of the brain. Rather it seems to be stored in a dynamic form and Pribram (1991) has argued that it may even be stored as some form of dynamic hologram. Memories are then re-created through activity in the brain. Since memory is an essential feature of self, the self is not localised at some point in the brain. The 'homunculus' is a global dynamical process systained by activity itself and stabilised by active information. Thus active information is essential to develop meaningful structures in thought.

Much of the information that we have available to us is not relevant except in particular circumstances. This means that much of our information is passive. Again we are always forgetting bits of information as well as being unaware of much more. In other words there is also plenty of inactive information in the world of thought! Therefore at a very general level, our proposals for the interpretation of quantum mechanics seem to suggest that there may not be such a great difference between matter and thought as the dualist supposes.

It is important to remember that the word *information* is not being used with the same meaning it has in everyday life. There it has a much more restricted meaning. It is a noun and as such seems to play a passive role and is used to point to "items of knowledge", lifeless forms such as a list of facts and figures. But as has already been indicated above, our use of the word 'information' emphasises activity and it is necessary to stress this active side of the notion of information as it is this aspect that seems to be relevant both to material process and to thought.

Let us now leave this specific aspect of the notion of information and return to consider the wider aspects of the radically new world view provided by the implicate order. Within it we can ask whether anything more can be said about the mind/matter relationship.

We can begin by highlighting a particular feature that is implicit in what has been said and actually is quite close to Bohr's own point of view. Bohr (1961) insisted that our immediate experience of quantum phenomena is through the macroscopic world which is described by classical physics. We call this world the manifest world. Recall that the word 'manifest' means literally "what can be held in the hand", or more generally, "what can be held in the hand, eye and mind". Everything in the classical world is constituted of very stable structures that are outside of each other and which interact only through local mechanical interactions.

Quantum phenomena with their interference effects, their nonlocality, and other puzzling features, belong to a world that is subtle. Again the word 'subtle' literally means "rarefied, highly refined, delicate, indefinable". It is clear that quantum phenomena cannot be "held in the hand" because any attempt to "hold" them produces an uncontrollable and unpredictable change. Each element participates irreducibly in all others. The absence of externality and separability makes this world very illusive to grasp in our physical instruments. It is a world that sustains itself intimately within the underlying implicate order.

Following on from this we propose that all processes have two sides, a manifest side and a subtle side. The subtle side is organised through active information and displayed in the manifest side that can be regarded as the self. In the case of quantum processes the active information is mediated by the quantum potential. When we go to quantum field theory we have the possibility of more than one level. This means that we have room to discuss various degrees of subtlety, each being revealed in its own relatively manifest level. Again in physics we have the relationships between the levels organised in terms of either the quantum potential or in terms of the superquantum potential, and, of course we also have possibility of a third level and so on.

We can now ask if there is anything like this going on in the mind/body relationship? Bohm (1980) argues there is and gives the following example. Suppose someone who is out walking on a dark night suddenly becomes aware of a suspicious movement in the shadows. Immediately there is an upsurge of involuntary and essentially unconscious activity; adrenaline flows, the heartbeat increases and neuro-chemicals of various kinds are released to produce other physical movements. As more perceptual information is received and the shadow is seen to be that of a friend, all the chemical activity dies down and eventually ceases. On the other hand if the perception is one of danger, the activity increases. Here we see that it is the active information that is organising chemical and other physical processes in the brain and indeed, in the whole body.

To what extent is this activity similar to what goes on at the quantum level? Clearly there are similarities, but at the same time there seems to be one important difference, namely, that in our subjective experience, action can be mediated by reflection in conscious thought. We can suspend physical activity and think the problem through before acting. This is in contrast to the electron where the action of the information is immediate. In this case there does not seem to be any possibility of any form of conscious activity.

However on further reflection it can be seen that the difference is not as great as it might at first sight appear. In the case of thought, this reflection involves the suspension of physical action to allow the process of thought to continue. But the suspension of physical activity is immediate on perceiving the need to do this. This perception acts at a higher level in the human thought process. These higher levels can only exist if a system is complex and structured enough to function in this manner. Thus the difference between mind and matter is one of complexity, but the principle is the same, so that the difference is not as great as we might expect. Processes involving mind are merely much more subtle. In this sense the emergence of consciousness is much closer to the views suggested by Searle (1992).

Our proposal is that in the brain there is a manifest (or physical) side and a subtle (or mental) side acting at various levels. At each level, we can regard one side the manifest or material side, while the other is regarded as the subtle or mental side. The material side involves electrochemical processes of various kinds, it involves neuron activity and so on. The mental side involves the subtle or virtual activities that can be actualised by active information mediating between the two sides. Thus it is the active information that provides the link between the two sides.

This approach is reminiscent of Whitehead's division of the process of concrescence into three stages. Stage I is regarded as the "physical pole" which he calls the responsive stage and is the seat of causal efficacy. Stage II is the supplementary stage which Whitehead calls the "mental pole". Whitehead also adds a third stage which he calls "satisfaction". This is a curious term which Epperson (2004) describes as meaning " the actualisation of one of the many potential integrations generated in the first two stages". Whether Stage III can be regarded as the mediation of some form of active information to generate the actualisation is not clear to me. Indeed I find Whitehead's language very difficult to penetrate. I would certainly not use the term "supplementary" to describe the subtle or mental side and I would certainly not use the word "satisfaction" to describe the linkage. Nevertheless the fact that Whitehead uses the terms "mental" and "physical" suggests that there is some similarity between the two approaches.

Furthermore what is clear in both approaches is that the "mental" and "physical" sides must *not* be thought of as actually distinct. Recall our discussion of the quantum particle where the field and the particle were different aspects of the same process. Thus the distinction between the manifest and the subtle sides is not to be thought of as distinct and separate processes. They are two aspects of the same process. The logical distinction of the two sides necessitates a logical linkage. Since these distinctions are descriptive rather than actual we have the possibility of varying degrees of subtlety and manifestness. This makes a hierarchy of levels possible, so that what is subtle at one level can become what is manifest at the next level and so on. In other words if we look at the mental side, this too can be divided into a relatively stable and manifest side and a yet more subtle side. Thus there is no real division between what is manifest and what is subtle and in consequence there is no real division between mind and matter, between psyche and soma. In this sense the subtle side involved in quantum phenomena can be regarded as having a primitive "mind-like" quality as Dyson (1997) suggested. There is no Cartesian dualism. We have a thorough going wholeness in which the mental and physical sides participate in each other.

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