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The Evolution of Consciousness

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Abstract

It is argued that the principles of classical physics are inimical to the development of a satisfactory science of consciousness. The problem is that insofar as the classical principles are valid consciousness can have no effect on the behavior, and hence on the survival prospects, of the organisms in which it inheres. Thus within the classical framework it is not possible to explain in natural terms the development of consciousness to the high-level form found in human beings. In quantum theory, on the other hand, consciousness can be dynamically efficacious: quantum theory does allows consciousness to influence behavior, and thence to evolve in accordance with the principles of natural selection. However, this evolutionary requirement places important constraints upon the details of the formulation of the quantum dynamical principles.

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1. The Inadequacy of Classical Mechanics as the Basis for a Science of Consciousness

Every major advance in science has involved an important conceptual development, and the incorporation of consciousness into physics should be no exception. The mapping out the empirical correlations between brain activity and consciousness will certainly contribute in an important way to our understanding of the mind/brain system, but there must also be conceptual progress on the theoretical problem of how to bring consciousness into concordance with the principles of physics.

Rational analysis of this problem hinges on one central fact: classical mechanics does not entail the existence of consciousness. Classical mechanics neither requires, demands, nor allows one to predict with certainty, the existence of (phenomenal) experience. The full content of nature, as it is represented in classical mechanics, resides in the locations and motions of particles, and the values and rates of change of local fields. There is nothing within the classical physical principles that provides a basis for deducing how a physical system "feels"—for deducing whether it is happy or sad, or feels agony or delight. There is no phenomenal hook or toe-hold within classical mechanics itself that can permit one to deduce, logically, simply from the principles of classical mechanics alone, the assured validity of assertions about the experiential aspects of nature. This is not a matter of lack of imagination, or inability to conceive new possibilities. It is a matter of basic principle. There is no basis within the principles of classical mechanics for a logical proof of the existence of a "feeling" because classical mechanics is a rationally closed conceptual system whose principles supply no more than is needed to determine the motions of particles and fields from the prior dispositions of these same variables themselves. This dynamical connection is established within a narrow mathematical framework that never refers to any phenomenal (i.e., psychological or experiential) quality.

Since classical mechanics is dynamically complete, with respect to all the variable with which it deals, namely the so-called "physical" variables, one has, with respect to the phenomenal elements of nature, four options: 1) identify the phenomenal elements with certain properies or activities of the physical quantities; 2) say that these phenomenal elements are not identically the same as any physical property or activity, but are companions to certain physical properties or activities, and that their presence in no way disrupts the classical dynamics; 3) accept some combination of 1) and 2); or 3) accept that phenomenal elements do affect the dynamics, rendering classical dynamics invalid.

The first three options are scientifically indistinguishable, and they share the common feature that the classical dynamical principles do not logically determine whether the proposed connection of the physical variables to our felt experiences, or to the analogous feelings in members of other species, is valid or not. So the connection to physical parameters of something so basic to science as our experienced knowledge of what is going on about us is not logically entailed by the basic dynamical laws. Consequently, the feelings that we experience become appendages whose existence could, from a logical point of view, be denied without violating the posited classical laws. The phenomenal aspects of nature would be, in this sense, epiphenomenal: the classical dynamical principles could be completely valid without the feelings that we experience being present in nature at all.

It is very likely true that any physical system that is built and behaves in a certain ways will also be conscious, and that this tight relationship between behavior and felt experience arises naturally out of the essential nature of the actual physical substrate. But the existence of such a connection would not mean that this tight relationship is a logical consequence of the principles of classical mechanics. On the contrary, it would mean rather that the principles of classical mechanics are incomplete because they fail to entail the existence of this naturally occurring aspect of nature, and are, moreover, necessarily false unless consciousness is epiphenomenal.

The epiphenomenal character of consciousness implied by classical mechanics cannot be reconciled with the naturalistic notion that consciousness evolved due to the survival advantage it conferred: epiphenomenal properties confer no survival advantage. Hence if the classical principles were taken to govern the dynamical process of nature then the presence in human beings of highly developed consciousness would be a double mystery: the basic dynamical principles would neither entail the existence of the phenomenal realities that populate our experiential realms, nor, given their existence, allow any natural dynamical explanation of how they could have evolved to this high state from simpler forms.

These considerations would be very destructive of the naturalistic program of science were it not for the fact that classical mechanics has already been found, by purely physical considerations, to be basically incorrect: it does not describe correctly the empirically observed properties of physical systems. This failing is not merely a slight inaccuracy. To get an adequate theoretical foundation for a description of physical processes the entire logical structure of classical mechanics had to be abandoned at the foundational level. It was replaced by a radically different logical structure that allows our experiences to play a key logical and dynamical role.

2. Quantum Mechanics and Consciousness.

The successor of classical mechanics is called quantum mechanics. The basic change is to a mathematical description that effectively converts the atomic particles to something of a radically different ontological type. In the new theory the "particles" can no longer be imagined to be tiny material objects of the kind encountered in everyday life, but merely smaller. They become more like nonlocalized elements of an information network, or of a knowledge structure. This ontological change infects everything made up of atomic constituents (and fields), and hence the entire physical world. Thus the basic conceptual problem that the founders of quantum theory had to solve was how, in the face of this dissolution of the substantive universe of classical mechanics, to find some new foundational structure upon which to base an adequate new physics.

Their solution was pragmatic and epistemological. No matter what the world 'out there' is really like, our direct experiences of it are just what they were before the quantum character of nature was discovered: they are of the same kind that they were when classical mechanics seemed adequate. Given this empirical fact, that "our experiences of the world" are "classically describable", in the sense that we can described them as if they were experiences of a world that accords at the macroscopic level with the concepts of classical physics, one can take experiences of this kind to be the foundational elements upon which to build the new science. Thus the founders of quantum theory constructed the new physics as a theory of statistical correlations between experiences of this kind: the basic realities of the new physical science became these "classically describable" experiences, and the physical world became an information network that connected these classically describable experiential realities to each other in a mathematically specified statistical way.

The important thing about this new conception of basic physical theory, in the context of the mind/brain problem, is that the experiential things are no longer left out. Rather they have moved to a central position. Thus we are no longer forced to graft the experiential aspects of nature into a physical theory that has no natural place for them, and that moreover excludes from the outset any possibility of their playing an irreducible dynamical role. Furthermore, since the elemental ingredients of the theory are information and knowledge, rather than material objects resembling little rocks, we are no longer faced with the ontological puzzle of how to build consciousness out of something so seemingly unsuited to the task as a collection of tiny rocks hurtling through space. On the contrary, in quantum theory the rock-like aspects of nature arise from certain mathematical features that inhere in idea-like qualities.

3. Quantum Ontologies

The original "Copenhagen" interpretation of quantum theory eschewed ontology: it made no attempt to provide a description of nature itself, but settled for a system of rules describing statistical correlations between our experiences (i.e., between our classically describable experiences of the world). Physicists have, by now, devised essentially three ontological pictures that could produce the same statistical connections as the earlier pragmatic system of rules. These ontologies are Everett's One-World/Many-Minds ontology, Bohm's Pilot-Wave Ontology, and the more orthodox Wave-Function-Collapse ontology associated with the names of Heisenberg, von Neumann, and Wigner. To get to the essential point of what consciousness can do it will be useful to describe briefly the essential features of these three ontologies.

In all three ontologies a key component of nature is the quantum state vector. This is a basic element in the quantum theory, and it can be represented in various equivalent ways. In the simplest way one decomposes it into components corresponding to various numbers of "particles" of various kinds, where the word "particle" initially means just that there is a set of three variables x, y, and z, and a "mass", and perhaps a few other (spin) variables for each such "particle". Then, for example, the component of the state vector corresponding to N spinless particles would be a function of 3N variables, namely the three variables x, y, and z for each of the N particles. This function is called the "wave function" of the N particles: it can be imagined to be something like a wave, or set of ripples, on a pond, where the different locations on the "pond" are specified now not by just two variables, as for an ordinary pond, but rather by 3N variables. This "wave", or set of ripples, evolves in time under the control of the Schroedinger equation, which causes the wave to propagate over this 3N-dimensional "pond". The essential feature of this propagation is that there is a tendency for the wave continually to divide further and further into ever finer separate branches that are narrowly focused and move off in different directions in the 3N-dimensional space. Each such branch corresponds, roughly, to a different classically describable possibility. For example, one such branch might correspond to the dead version of Schroedinger's notorious cat, whereas another branch would describe the alive version. The various separate branches become far apart on the 3N-dimensional pond, and hence come to evolve independently of each other: each branch quickly comes to evolve in almost exactly the way that it would evolve if the various branches from which it is diverging were not present at all. On the other hand, various branches that are far apart and independently evolving in 3N-dimensional space could be sitting right on top of each other if one were to project these branches down onto the ordinary 3-dimensional space that we seem to inhabit: the independently evolving dead and alive cats could be confined, as far as appearances are concerned, to the same small 3D cage.

The basic interpretational question in quantum theory is how to comprehend these many co-existing "branches" of the universe, only one of which we ever observe.

I think almost every physicist who starts to think diligently about this question is led first (on his own if he has not already heard about it) to a natural interpretation that Everett [1957] first described in detail. This is the idea that, because the Schroedinger equation is the quantum mechanical analog of Newton's equations, which were supposed to govern the evolution of the universe itself, the physical world should have a really existing component corresponding to each of the branches generated by the Schroedinger equation. Since each of these branch evolves essentially independently of every other one, the realm of consciousness associated with each branch of the wave function of a person's brain must be dynamically independent of the realms of consciousness associated with every other branch. Thus each conscious observer should be aware only of the classically describable world that corresponds to the branch of the universe (as specified by the wave function) that contains the corresponding branch of his brain: the branches of the wave function of his brain that are parts of other branches of the universe should correspond to different independently evolving realms of experience, namely to realms of experience corresponding to these other "classically describable" branches of the universe.

The existence of these essentially independently evolving branches of the wave function follows directly from the basic equations of quantum mechanics, and thus seems reasonable from a physicist's point of view, even though it leads to the strange idea that the complete reality is a super-world that is populated with a plethora of really existing ordinary-worlds, only one of which is represented in any individual realm of consciousness.

The logical simplicity of this model is undermined , however, by a logical difficulty. It has to do with the statistical predictions that are the heart of quantum theory. The quantum evolution in accordance with the Schroedinger equation causes each branch generally to divide into sub-branches, and quantum theory assigns to each sub-branch a relative statistical weight, and gives to this relative statistical weight an empirical meaning. This meaning entails that if a person finds himself to be on a branch then the probability that he will subsequently find himself to be on a particular sub-branch will be specified by the afore-mentioned relative statistical weight of that sub-branch. Thus if a sub-branch has a very low relative statistical weight, according to the theory, then quantum theory predicts that the chance is very small that a person who experiences himself at one moment to be on the original branch will later experience himself to be on that sub-branch.

In order to provide a basis for this notion of probability one must have something that can belong to one branch OR another. In the above discussion this something was a realm of consciousness: each realm of consciousness is considered to belong to some particular branch, not to all branches together. However, in the state vector, or its representation by a wave function, all of the branches are conjunctively present: a toy boat might be sitting on one branch OR another branch, but the pond itself has this ripple AND that ripple, AND that other ripple etc.. Thus in order to deal with probabilities one is forced to introduce something that is logically different from the quantum state or wave function that the basic principles of quantum mechanics provide. This move constitutes the introduction of a new kind ontological element: the theory becomes essentially dualistic, in contrast to the monistic structure of classical mechanics. Consciousness is a new kind of thing that, quite apart from its phenomenal character, has mathematical properties different from those of the "physical" part of nature represented by the wave function.

Once it is recognized that the realms of consciousness are not simply direct carry-overs from the quantum state, but must have essentially different logical properties, it appears that it would be more parsimonious and natural to have, for each person, a single realm of consciousness that goes into a single branch rather than having to introduce this new kind of ontological structure that, unlike the wave function, divides DISJUNCTIVELY into the various branches. This option produces a one-mind variation of Everett's many-minds interpretation. The one-mind version has been promoted by Euan Squires [1990].

David Bohm [1952, 1993] solves this "AND versus OR" problem by introducing in addition to the quantum state, or wave function, not consciousness but rather a classical universe, which is represented by a moving point in the 3N-dimensional space. Bohm gives equations of motion for this point that cause it to move into one of the branches OR another in concordance with the quantum statistical rules, for a suitable random distribution of initial positions of this point. Thus Bohm's theory is also dualistic in the sense of having two ontological types, one of which, the quantum state, combines the branches conjunctively, and the other of which, the classical world, specifies one branch OR another.

The great seeming virtue of Bohm's model is that, like classical mechanics, it is logically complete without bringing in consciousness. But then any later introduction of consciousness into Bohm's model would, from a logical point of view, be gratuitous, just as it is for classical mechanics: consciousness is not an integral and logically necessary part of the theory, but is rather a dangling epiphenomenal appendage to a theory whose chief virtue was that, like classical mechanics, it was logically and dynamically complete without consciousness.

Bohm's model is, moreover, nonparsimonious: it is burdened with a plethora of empty branches that evolve for all eternity even though they have no influence on the motion of the classical world. Squires' model has a similar defect: it has a plethora of empty (of consciousness) branches that evolve for all eternity, but have no effect on anyone's experiences. Everett's many-minds interpretation is nonparsimonious for the opposite reason: it has for each individual human being, Joe Doe, a plethora of minds only one of which is needed to account for the empirical facts. It is the presence of these superfluous elements in each of these interpretations that causes many physicists to turn away from these "unorthodox" interpretations.

The most parsimonious theory is the Bohr/Heisenberg/von-Neumann/Wigner wave-function-collapse model. This model: 1) accepts Bohr's view that our experienced knowledge is an appropriate reality upon which to build physical theory; 2) accepts Heisenberg's view that transitions from potentiality to actuality are a basic component of nature; 3) accepts von Neumann's identification of these transitions with abrupt changes of the quantum state of the universe; and 4) accepts Wigner's proposal (attributed by Wigner to von Neumann) that our conscious experiences are associated with brain events that actualize new quantum states. This association of the experiential events upon which Bohr based the whole theory with brain events that are just are special cases of the general collapse events of Heisenberg and von Neumann brings closure to the theory, and produces a natural basis for a science of consciousness.

THE CAUSAL EFFICIENCY OF KNOWINGS

There is no empirical evidence that collapse events occur outside human brains. But decoherence effects would make them difficult to detect even if they did occur. Thus the strategy of those who construct models of collapses 'out there' based on physical criteria is to make these criteria such that the collapses do occur 'out there' where classical intuitions would like them to occur, but such that decoherence effects make them invisible.

In the present approach the criterion for a collapse is that it be identifiable with a knowing.

A key question is whether such a collapse would have any effects in a warm wet brain that are different from what a classical-type or Bohm-type theory would predict?

In quantum theory each collapse is instigated by the posing of a question: Nature answers 'Yes' or 'No'. If Nature answers 'Yes', then the prior state collapses to a new state that incorporates the new knowing: if Nature answers 'No', then the collapse is to a state that is the prior state with the part corrsponding to the 'Yes' answer removed. Thus the 'No' answer leaves a *hole*, so to speak. But the Schroedinger equation is essentially the equation of hydrodynamics (Feynman, 1965), which means that if a part is removed, then parts of the surrounding environment tend to rush in and fill up the hole. Thus if the same question is posed repeatedly then, in much the same way as one can nearly empty a bucket by taking out small scoops always from the same place, this action effectively sucks probability into the positive answer to the repeatedly posed question. The positive answer must set the brain on a new course, which it does if what is actualized is a template for action..

The relevance of this to brain dynamics is that the brain is essentially a search engine that is searching, in a particular context, represented by its current state, for a template for action that will initiate an appropriate response of the body/brain. In a classical model "a miss is as good as a mile": if the search does not actually hit the perhaps very small but deep well that constitutes the solution it will not fall in. It can pass very close, but that is no good at all. But if in quantum theory one puts in an absorbing patch that represents the activation of the large-scale response, the wave function tends to get sucked into that patch. (Quantum theorists can consider, for a ground state wave function in a one dimensional ring with potential $V = 0$, the effect of adding to V a large imaginary part over a small segment: in the classical analog only a small fraction of the emsemble will ever find the 'hole', but in the quantum case everything will eventially get sucked into it.)

Thus this quantum-sucking effect can in principle produce large enhancements of search efficiency and speed over what the classical principles or Bohm's model can give.

These performance-enhancing effects are generated by the quantum rules themselves: no 'biasing' (i.e., violation) of the quantum mechanical rules is invoked or involved.

Moreover, these effect is are local in the sense that they do not depend on the existence of difficult-to-achieve phase coherence over large distances in the brain.

NATURAL SELECTION AND THE EVOLUTION OF CONSCIOUSNESS

In a naturalistic theory one would not expect consciousness to be present in association with a biological system unless it had a function: nothing as complex and refined as consciousness should be present unless it enhances the survival prospects of the system in some way.

This requirement poses a problem for a classically described system because there consciousness is causally non-efficatious: it is epiphenomenal. Its existence is not, under any boundary conditions, *implied* by the principles of classical physics in the way that what we call "a tornado" is , under appropriate boundary conditions, implied by the principles of classical physics. Consciousness could therefore be stripped away without affecting the behavior of the system in any way. Hence it could have no survival value.

Consider two species, generally on a par, but such that in the first the survival-enhancing templates for action are linked to knowings, in the way described above, but in the second there is no such linkage. Due to the quantum effects described in the preceding section the members of the first species will actualize their survival-enhancing templates for action faster and more often than the members of the second species, and hence be more likely to survive.

I need not specify at this point just what the rules are that define possible knowings, and their connections to projection operators, beyond saying they should cover the one case we know about, namely the case of human beings.

But if there are such rules, then one would expect that biological systems would exploit them by linking their survival-enhancing templates for action to their knowings, since this would, by virtue of the quantum- enhancement effect, make them more likely to survive. If the possible knowings extend from very primitive knowings to very complex ones, then we have a way of accounting for the gradual evolution of consciousness hand-in-hand with the evolution of the body/brain.

WHAT IS CONCSIOUSNESS?

When scientists who study consciousness are asked to define what it is they study, they are reduced either to defining it in other words that mean the same thing, or to defining it ostensively: to directing the listener's attention to what the word stands for in his own life. In some sense that is all one can do for any word: our language is a web of connections between our experiences of various kinds, including sensations, ideas, thoughts, and theories.

If we were to ask a physicist of the last century what an "electron" is, he could tell us about its "charge", and its "mass", and maybe some things about its "size", and how it is related to "atoms". But this could all be some crazy abstract theoretical idea, unless a tie-in to experiences is made. However, he could give a lengthy description of this connection, as it was spelled out by classical physical theory. Thus the reason that a rational physicist or philosopher of the ninteenth century could believe that "electrons" were real, and perhaps even "more real" than our thoughts about them, and believe that he actually understood what they were, is that they were understandable as parts of a well-defined mathematical framework that accounted—perhaps not directly for our experiences themselves—but at least for how the contents of our experiences hang together in the way they do.

Now, however, in the debate between materialists and idealists, the tables are turned: the concepts of classical physics, including the classical conception of tiny electrons responding only to aspects of their local environment, absolutely cannot account for the macroscopic phenomena that we see before our eyes. On the contrary: the only known theory that does account for all the empirical phenomena, and is not burdened with extravagent needless ontological excesses, is a theory that is neatly formulated directly in terms of our knowings: nature seems to be allowing itself to adhere to a principle of parsimony. So the former reason for being satisfied with the idea of an electron, namely that it is part of a mathematical framework that accounts quantitatively for the contents of our experiences, and that it gives us a mathematical representation of what is persisting during the intervals between our experiences, has dissolved insofar as it applies to the classical idea of an electron: it applies now, instead, to knowings.

Appealing more directly to intuitions the classical physicist might have resorted to a demonstration with tiny "pith balls" that attract or repel each other due to (unseen) electric fields, and then asked the viewer to imagine much smaller versions of what he then sees before his eyes. This would give the viewer a direct intuitive basis for thinking he understood what an electron is.

This intuitive reason for the viewer's being satisfied with the notion of an electron as an element of reality was that it was a generalization of something very familiar: a generalization of the tiny grains of sand that are so common in our ordinary experience, or of the tiny pith balls that he has been shown.

There are, of course, no things more familiar to us than our own experiences. Yet they are elusive: each of them disappears almost as soon as it appears, and even more rapidly if examined closely. It leaves behind only a fading impression, and fallible memories.

However, I shall try in this section to nail down a more solid idea of what a conscious experience is: it unifies the theoretical and intuitive aspects illustrated above.

The metaphor is the experienced sound of a musical chord.

We have all experienced how a periodic beat will, when the frequency is increased, first be heard as a closely spaced sequence of individual pulses, then as a buzz, then as a low tone, and then as tones of higher and higher pitch. A tone of high pitch, say a high C, may to some listeners be experienced as nothing more or less than a finely spaced sequence of individual pulses, but I think it is to most hearers, at least primitively, something experientially different: only when attended to in a particular way would it be recognized as a sequence of pulses.

The same goes for major and minor chords: they are experienced differently, as a different gestalts. Each chord, as normally experienced, has its own unique total quality, although an experienced listener can attend to it in a way that may reveal the component elements.

One can generalize still further to the complex experience of a moment of sound in a Beethoven symphony.

These examples show that a state that can be described physically as a particular combination of vibratory motions is experienced as a particular experiential quality: what we cannot follow in time, due to the rapidity of the variations, is experienced as a direct awareness of quality that is a gestalt-type impression of the entire distribution of energy among the sensed frequencies.

The aspect of brain dynamics that, at least according to my theory (Stapp, 1993), corresponds to a conscious experience is a complex pattern of reverberating patterns of excitations along neural pathways. It is exactly such a pattern that, once it has reached a stable steady state, is a template for immediate further brain action. Its actualization by a quantum event initiates that action, and it also pulls out of a morass of alternative competing and conflicting patterns of neural excitations a single coherent energetic combination of reverberating patterns that initiates, quides, and monitors, an ongoing coordinated evolution of neural activities. The experience that accompanies this suddenly picked out "chord" of reverberations is, I suggest, the quality that constitutes the direct awareness of this complex pattern of reverberations. Because of the far greater complexity of the sensed combinations of reverberations in these templates for action, as contrasted to those that represent auditory sounds, the experiential qualities must be more complex: we need not only the already quite rich set of experiential qualities that are our knowings of the reverberations that correspond to auditory vibrations , but the far greater richness of the experiential qualities that constitute our knowings of the far more complex patterns of reverberations that represent, within Hilbert space, a visual experience. Still other qualities constitute our knowings of other complex patterns of reverberations.

The most subtle shades of meaning contained in a thought should, within a naturalistic approach, reside in the patterns of reverberations that produce all the actions initiated by that thought, which, according to the present theory, is exactly the knowing of that pattern of reverberations. The fact that the single thought has the temporal slices that allow causal structure to be grasped, and different other thoughts to be compared (Stapp, 1993) means that the full richness of meaning is in the pattern of reverberations.

So in place of the analogies to pebbles and pith balls that informed our intuitions about the unseen electrons, I suggest using the analogy to the connection of the physical vibrations in someone's ear to the sounds he experiences.

This connection is quite intuitive, because we can experience the gradual transition from vibration to sound, and indeed be almost directly aware that the experiencing of a sound is the knowing of the existence of a vibration. Thus this connection provides for an intuitive grasp of what a human experience is: it is the direct awareness of the neural reverberations that are suddenly actualized by a quantum event of knowing. Such an event exactly adds to the universal body of knowledge represented by the quantum state of the universe the condition that the existence of this directly experienced chord of reverberations is a new known fact.

Further details can be found in Stapp (1993, 1994, 1996a,b).

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