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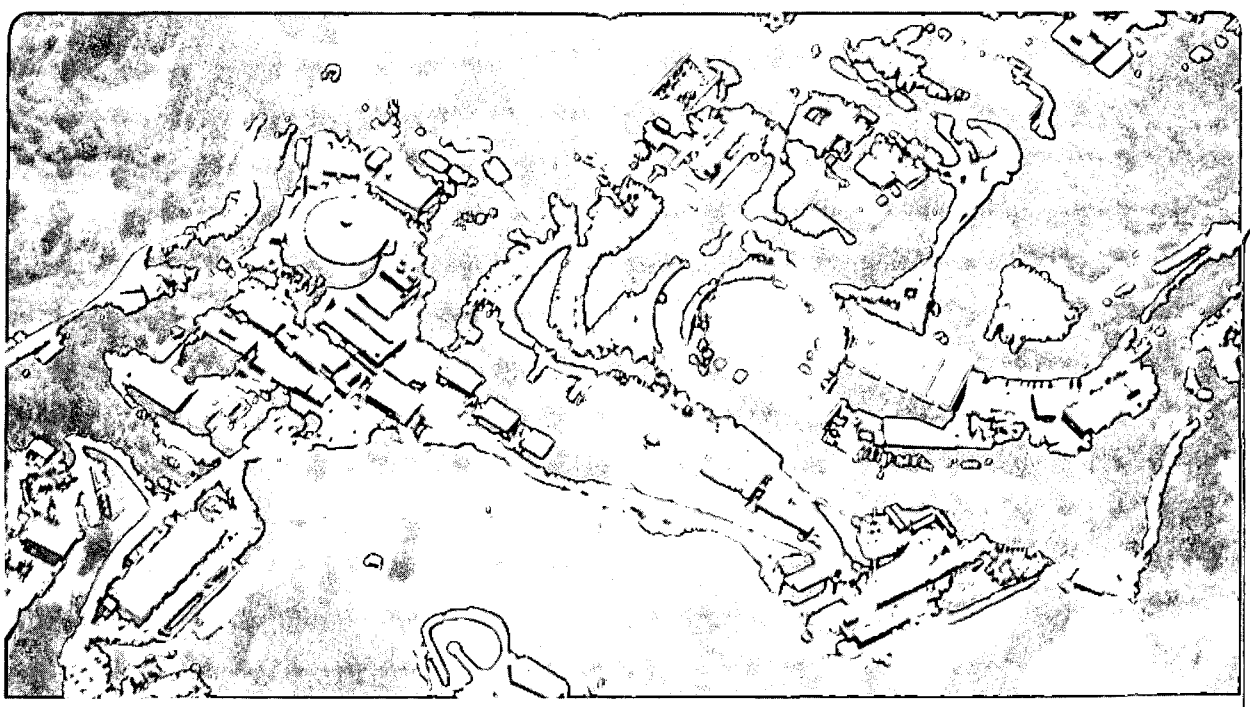

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Quantum Theory and the Place of Mind in Nature. *

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Classical physics can be viewed as a triumph of the idea that mind should be excluded from science, or at least from the physical sciences. Although the founders of modern science, such as Descartes and Newton, were not so rash as to proclaim that mind has nothing to do with the unfolding of nature, the scientists of succeeding centuries, emboldened by the spectacular successes of the mechanical view of nature, were not so timid, and today we are seeing even in psychology a strong movement toward "materialism", i.e., toward the idea that "mind is brain". But while psychology has been moving toward the mechanical concepts of ninetieth-century physics, physics itself has moved in just the opposite direction.

The mentalistic bias of contemporary physics is perhaps best summarized in Heisenberg's statement that "we are finally led to believe that the laws of nature that we formulate mathematically in quantum theory deal no longer with the particles themselves but with our knowledge of the elementary particles. ... The conception of the objective reality of the particles has thus evaporated in a curious way, not into a fog of some new, obscure, or not yet understood reality concept, but into the transparent clarity of a mathematics that represents no longer the behavior of the elementary particles but rather our knowledge of this behavior." (Heisenberg 1958a, p. 99-100)

This shift in the physicist's conception of nature, or at least in his conception of his *theory* about nature, away from the mechanical and toward the experiential is expressed also by Bohr's statements: "In our description of nature the purpose is not to disclose the real essence of phenomena but only to track down as far as possible relations between the multifold aspects of experience". (Bohr 1934, p. 18). "As the goal of science is to augment and order our experience ... ." (Bohr 1958, p.88)

Bohr and Heisenberg each sought to deflate the idea that either he, or quantum theory itself, was asserting that the character of nature herself was essentially mental. Bohr emphasized that quantum theory was merely a tool for making predictions about our experiences: "Strictly speaking, the mathematical formalism of quantum mechanics and electrodynamics merely offers rules of calculation for the deduction of expectations about observations obtained under well defined conditions specified by classical physical concepts." (Bohr 1963, p.60) Heisenberg went even further: "If we want to describe what happens in

an atomic event we have to realize that the word 'happens' ... applies to the physical not the psychical act of observation, and we may say that the transition from the 'possible' to the 'actual' takes place as soon as the interaction between the [atomic] object and the measuring device, and thereby with the rest of the world has come into play; it is not connected with the act of registration of the result in the mind of the observer. The discontinuous change in the probability function, however, takes place with the act of registration, because it is the discontinuous change in our knowledge in the instant of registration that has its image in the discontinuous change in the probability function. (Heisenberg 1958b, p.54)

The final sentence affirms Heisenberg's position that the mathematical probability function of quantum theory represents "our knowledge". However, the statements that precede it affirm his belief that there are also some real "happenings" outside the minds of the human observers, and that these external events have the character of transitions of the "possible" to the "actual".

To describe these external events themselves in mathematical form one can introduce the idea of an *objective wave function*— a wave function that is like the one of Bohr and Heisenberg with respect to its mathematical properties (i.e., evolution via the Schrodinger equation etc.), but that represents the external world itself, and changes when the transitions from "possible" to "actual" take place, rather than with the registration of a result in the mind of the observer/scientist. This procedure would seem to be a reasonable step toward providing a conceivable description nature herself, since it would allow the detailed and precise mathematical properties represented in quantum theory to be understood directly as mathematical characteristics of the world itself. This transformation can be termed the *ontologicalization* of quantum theory: it converts that theory from a structure conceived to be a mere tool for scientists — a tool to be used for very limited purposes — to a putative description of nature herself.

If we follow this tack, and endeavor to construe the mathematical structure represented by quantum theory as a feature of the world itself, then we may ask: What is the *nature* of that world? What *sort* of world do we live in?

The world represented by an ontogically interpreted quantum theory, with the quantum jumps representing transitions from "possible" to "actual", would

be a strange sort of beast. The evolving quantum state, although controlled in part by mathematical laws that are direct analogs of the laws that in classical physics govern the motion of "matter", no longer represents anything substantive. Instead, this evolving quantum state would represent the "potentialities" and "probabilities" for actual events. Thus the "primal stuff" represented by the evolving quantum state would be idealike in character rather than matterlike, apart from its conformity to mathematical rules. On the other hand, mathematics has seemed, at least since the time of Plato, to be more a resident of a world of ideas than a structure in the world of matter. Hence even this mathematical aspect of nature can be regarded as basically idealike. Indeed, quantum theory provides a detailed and explicit example of how an idealike primal stuff can be controlled in part by mathematical rules based in spacetime.

The actual events in quantum theory are likewise idealike: each such happening is a *choice* that selects as "the actual", in a way not controlled by any known or purported mechanical law, one of the potentialities generated by the quantum mechanical law of evolution.

In view of these uniformly idealike characteristics of the quantum physical world, the proper answer our question "What sort of world do we live in?" would seem to be this: "We live in an *idealike* world, not a matterlike world." The material aspects are exhausted in certain mathematical properties, and these mathematical features can be understood just as well (and in fact better) as characteristics of an evolving idealike structure. There is, in fact, in the quantum universe no natural place for matter. This conclusion, curiously, is the exact reverse of the circumstance that in the classical physical universe there was no natural place for mind.

These remarks may appear to be nothing but a word game. But I think not. The change in our words indicates a change in our perception. By changing our perception of the kind of world we live in we change our perception of the possibilities. If some of the possibilities opened up by this altered perception of the basic nature of the physical world can be actualized within science then this change of words and perceptions will certainly count for something.

One possibility immediately opened up by this change is the possibility of integrating human consciousness into the physical sciences. This possibility was effectively blocked off when physical science meant, in the final analysis,

classical physics. For there is an enormous conceptual gulf between the classical physicist's conceptualization of the physical world and the psychologist's conceptualization of the mental world. The essence of the classical physicist's conception of matter is its local-reductionistic nature: the idea that the physical world can be decomposed into elementary local quantities that interact only with immediately adjacent neighbors. But conscious thoughts appear to be complex wholes, not merely at the functional level but also as directly experienced. Insofar as the experienced quality of a conscious thought constitutes its essence it is not possible to conceptualize a thought as a resident of the physical world, as that world was conceived of in classical physics. To bring a human conscious thought into the physicist's conception of the physical world one needs, within that conception, something having, *in its essence*, the integrity and complexity of that thought. The world as it is conceived of in classical physics is essentially reductive and therefore admits no essentially complex wholes.

This problem of unity is brought into clear focus by Daniel Dennett's recent book *Consciousness Explained* (1991). The thesis of the book is that brain processes proceed in "parallel pandemonium", with each of the processing units doing its own thing. The problem is then to bring the outputs of all these processes together into the integrated forms that we seem to experience in our stream of conscious thoughts. Dennett argues that this integration is, in fact, not possible, and hence that *our thoughts cannot be what they seem to be.*

This conclusion may indeed by what would emerge from a classical conception of what is going on in a human brain. But quantum theory opens completely new vistas. For the actual event in quantum theory can perfectly well be the actualization, *as a unit*, of an entire high-level pattern of neural firings. Such a pattern could have all of the complexity of a conscious thought, and yet be, in essence, a single actualized structure. From a logical point of view we have, therefore, the foundation of a rational way of linking conscious thoughts into the physicist's conception of nature.

It is, of course, one thing to have the logical basis of a rational way of integrating conscious thoughts into the physical sciences and another thing to have a consistent and coherent theory that really achieves this. There are the problems of explaining the linkage of brain states to the functional efficacy of the conscious thoughts and to the experiential qualities of conscious thoughts.

Yet neither of these problems seems to be in principle beyond the bounds of rational explanation, within the quantum framework, which as explained earlier provides an intricate tapestry of idealike qualities.

The line of thinking described above has led to a serious attempt (Stapp 1993) to bring human conscious experience into the quantum mechanical description of nature. This endeavor, though hardly complete, is, I believe, sufficiently successful to warrant considerable optimism as regards the prospects of ultimate success: a great deal of empirical information that had seemed very puzzling from a classical point of view now falls neatly into place.

In view of these developments I believe that the verdict of history will be that the Copenhagen interpretation was a half-way house: it was a right face that was the first step of an about face.

The scientific community has, rightly, a considerable amount of intertia. A complete turn around on the basic classical idea that mind should be rigorously excluded from the theory of the workings of the material universe was neither possible nor warranted during the twenties and thirties. Any attempt to correlate the revolutionary findings in the domain of atomic physics to the subtleties of the connection between mind and brain would have been extravagantly premature in view of the then-prevailing rudimentary state of our understanding of the workings of the brain. The appropriate course of action was first to see how far the new quantum ideas would carry us in domains that were under better empirical control.

During the past twenty years, however, the Copenhagen interpretation has lost a good deal of its hold on the minds of physicists. The words of Murray Gell-Mann (1979, p.29) give an indication of this shift: "Niels Bohr brain-washed a whole generation of physicists into believing that the problem had been solved fifty years ago".

The reasons for this change in attitude are many and diverse. One important reason is the expansion of the scope of quantum theory. The theory was originally designed to cover the domain of atomic physics, and was therefore concerned things with that were far beyond the range of our direct observation, and were thus approachable only indirectly with the aid of sophisticated measuring devices. Now, however, a problem that looms large in the minds of physicists is

quantum gravity, which deals with quantum effects at the creation of the universe, and in the evolution of black holes. These phenomena are quite unlike the laboratory experiments in atomic physics that physicists were focussing on during the beginning of the century. The atomic-physics format of preparation-then-measurement fails to apply these new problems. On the other hand, the ontological approach is far more demanding in terms of logical cohesion. The additional constraints imposed by the demand for a coherent ontology can provide guidance in our attempts to extend physical theory into the interesting new domains.

A second reason for the loosening of the grip of the Copenhagen interpretation is the fall out from the 1964 paper of John Bell. The startling character of Bell's results caused physicists to take a careful look at the whole Bohr-Einstein controversy, and this left many of them with an uneasy sense that something important was perhaps being obscured by Bohr's subtle epistemological reasonings, which did not clearly do justice to the arguments of Einstein pertaining to locality.

A third reason for the fading influence of the Copenhagen interpretation is the construction by David Bohm (1952) of a thoroughly realistic model that reproduces all of the predictions of quantum theory. This model laid to rest an opinion that was in the background of Copenhagen thinking, namely the idea that it was simply impossible to understand atomic phenomena in a realistic way. Although most physicists did not accept the idea that Bohm's simple model describes the way things really work, they were nonetheless quickly disabused of the impression that Bohr (or von Neumann) had showed that all realistic approaches were necessarily doomed to fail.

A fourth reason lies in the philosophical climate of the times. During the early part of this century physicists were reeling from the impact of the loss of the "either" and "absolute time". The whole idea that the universe could be understood in a completely clear mechanical way had been shattered. How could there be waves in a void: waves in a space devoid of a medium? How could one understand the unfolding of our thoughts if there were no similar unfolding of nature herself; i.e., if the whole of spacetime history already "exists", as relativity theory seemed to require. The swallowing of such mysteries seemed to condition physicists not to balk at the even greater mysteries that quantum

theory left unresolved. Furthermore, the parallel behavioristic movement in psychology, which also focussed on measurable quantities at the expense of any understanding of the unfolding stream of conscious thoughts, seemed to place all of science on the same operational track.

Now, however, the behaviorist approach to psychology seems to have failed, for technical reasons (Baars, 1986). In psychology as in physics scientists are finding that increasingly complex models are needed to account for the complexity of the empirical data. But in the search for suitable complex models some orientation is needed. The data alone is insufficient: one needs some philosophy, and not merely an austere philosophy that recommends exclusive focussing upon the empirical facts obtained in a single narrow discipline. The insufficiency of the data in the various narrow disciplines, taken separately, is forcing scientists to bring into their theorizing information from an increasingly broad band of fields. Now in physics, for example, the problem of the innermost structure of the atoms is intertwined with the problem of the birth of the entire universe. Particle physics, astrophysics, and cosmology have merged into one field, at least at the level of theory.

Bold conceptions of large scope are needed to tie all these things together. The epistemological formulation of the Copenhagen interpretation seems, in the face of this complex situation, insufficiently helpful. Einstein's (1951) words in this connection are worth recalling: "It is my opinion that the contemporary quantum theory by means of certain definitely laid down basic concepts, which on the whole are taken over from classical physics, constitutes an optimum formulation of [certain] connections. I believe, however, that this theory offers no useful point of departure for future development."

If what Einstein was judging to be insufficient was a science based upon the separation of the world into an ineffable nonclassical reality, and a then-unexplained classical character of our perceptions of that reality, then his judgement probably accords with the contemporary developments in science. But if, on the other hand, the nonclassical mathematical regularities identified by quantum theory are accepted as characteristics of the world itself, a world whose primal stuff is therefore essentially idealike, and if, moreover, these mathematical properties account in a natural and understandable way for the classical characteristic of our conscious perceptions, as they seem to do (Stapp 1993), then we

appear to have found in quantum theory the foundation for a science that may be able to deal successfully in a mathematically and logically coherent way with the full range of scientific thought, from atomic physics, to biology, to cosmology, including also the area that had been so mysterious within the framework of classical physics, namely the connection between processes in human brains and the stream of human conscious experience.

Reference List

Baars, Bernard J. (1986) *The Cognitive Revolution in Psychology.* New York: Guilford Pr.

Bohm, David (1952) "A suggested interpretation of quantum theory in terms of 'hidden' variables I." *Physical Review* 85:166-179.

Bohr, Niels (1934) *Atomic Physics and the Description of Nature.* Cambridge: Cambridge University Press.

Bohr, Niels (1958) *Atomic Physics and Human Knowledge.* New York: Wiley .

Bohr, Niels (1963) *Essays 1958/62 on Atomic Physics and Human Knowledge.* New York: Random House.

Dennett, Daniel (1991) *Consciousness Explained.* New York: Little, Brown and Co.

Einstein, Albert (1951) In *Albert Einstein Philosopher-Scientist,* ed. P.A. Schilpp, New York: Tudor Publishing Co.

Gell-Mann, Murray (1979) In *The Nature of the Physical Universe, the 1976 Nobel Conference.* New York: Wiley.

Heisenberg, Werner (1958a) *Daedalas* 87 95-108

—— (1985b) *Physics and Philosophy.* New York: Harper and Rowe.

Stapp, Henry P. (1993) *Mind, Matter, and Quantum Mechanics.* Heidelberg: Springer-Verlag.

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