Cognitive repression in contemporary physics

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After more than 50 years of unquestionable success as a theory, questions about the interpretation of quantum mechanics continue to plague both physicists and philosophers. It is argued here that discussions about the meaning of quantum mechanics remain stymied as a result of the failure of physicists to formulate a cognitive paradigm adequate to their theory. The conventional interpretations which they offer can be seen as inadequate in one of two ways — implicitly, they retain one or the other of the two basic tenets of classical physics, the objectivity or the knowability of nature. This, it is argued, can be viewed as a form of cognitive repression of knowledge acquired, but not yet assimilated. A psychological explanation for the persistence of classical beliefs is proposed.

Piaget has invited the comparison between the historical development of scientific thought and the cognitive development of the child. Both, it is suggested, proceed through the emergence of discrete stages of structural organization, each stage bringing with it new possibilities of conceptual integration, and, concurrently, the possibility of a verbal articulation of the new level of organization perceived. Prior to the establishment of a new conceptual structure, knowledge already present in nonverbal forms (in, e.g., sensorimotor rather than representation schemes) finds no avenue of expression, and, to the extent that it jars with earlier established structures, demands cognitive repression. Piaget[1] tells us that an action schema which "cannot be integrated into the system of conscious concepts is eliminated ... (and) repressed from conscious territory before it has penetrated there in any conceptualized form." Caught in a transition between stages, the child, when pressed to articulate perceptions requiring cognitive structures which are not yet available, displays confusion, denial and avoidance—a disequilibrium strikingly reminiscent of the mechanism of affective repression.

In this paper, I want to suggest that the history of science exhibits similar transitional periods, and that a particularly notable instance is to be found in contemporary physics, Today, 70 years after the Newtonian world view received its first jolts, profound confusion remains about the implications of the revolution initiated first by relativity, and shortly after by quantum mechanics. This confusion is as evident among physicists as it is among the philosophical and lay public. Here, however, I want to focus on the confusion implicit in the minds of physicists, for it is they who have access to the knowledge necessitating this revolution, while philosophers and laymen are of necessity dependent upon the physicists to communicate what it is that they know. Even among physicists, a comfortable, stable representation of the new integration required, particularly by quantum mechanics, is yet to be achieved; its absence is marked by a remarkable array of interpretations and partial accommodations, thinly veiled by a token conformity and consensus.

This last point requires emphasis and elaboration. Physicists display an extraordinary confidence in the status of quantum mechanics coupled with a general reluctance to discuss its implications. Confidence in the theoretical status of quantum mechanics is amply justified by more than 50 years of empirical support; what is at issue is the juxtaposition between the confidence in the interpretability and "sense" of this theory and the simultaneous reluctance to discuss questions of interpretation. The ongoing, often intensely heated debates about how quantum mechanics *is* to be interpreted are generally confined to a small group of philosophically inclined physicists. For the rest, for the majority of physicists, questions about the meaning of quantum mechanics have been "taken care of" by what is loosely called the "Copenhagen Interpretation." Further inquiry is then discouraged by the implicit or explicit dual message that (i) the survival of such questions is evidence only of the inquirer's failure of understanding and (ii) such questions are "just" philosophy, and hence not legitimate. If, however, one persists, and attempts to pursue an understanding of *how* the "Copenhagen Interpretation" resolves the thorny questions raised by quantum mechanics, either through discussion or through an examination of the literature, one finds that there is not one "Copenhagen Interpretation." Rather the term seems to consitute a kind of umbrella under which a host of different, often contradictory positions coreside. Such a recognition provides *de facto* evidence of defense and evasion; the particular substance of disagreement displayed illuminates what it is that is being evaded. In particular, that which is being evaded is the need for a cognitive structure radically different from the prior existing structure. The prior structure, which I call "classical objectivism," consists of a set of formulations about the world and our relation to it as knowers which has determined the character of science since its inception. The confusion surrounding the interpretation of quantum mechanics derives from errors which serve the function of retaining one or more components of the classical orientation.

Schrödinger has identified the two fundamental tenets of science as the beliefs that nature is (i) objectifiable and (ii) knowable. By the first is meant the assumption of an objective reality, split off from and having an existence totally independent of us as observers. This is the principle that embodies the radical dichotomy between subject and object characteristic of the classical stance. It contains within it the implicit assumption that that reality which exists outside of us is composed of objects—a rider which although not logically necessary, is in practice an almost inevitable concomitant, if not precursor, of the classical view. The reason for this conjunction is, no doubt, that a world composed of clearly delineated objects both invites

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and facilitates the schism in which the subject is severed from even its own corporeal, objective existence. It is the move which is usually held responsible for, in the words of Koyre, "the splitting of our world in two."

But a world view which posits a total separation between us as subject and reality as object is by itself of no interest to science since it permits no knowledge. Science is born out of the addition of Schrödinger's second tenet—out of the confidence that nature, so objectified, is indeed knowable. Not only is a connection between us as knowers and the reality to be known here posited, but the connection posited is of an extraordinarily special nature. For most scientists, it implies a congruence between our scientific minds and the natural world which permits us to read the laws of reality without distortion, without error, and without omission. Belief in the knowability of nature is implicitly a belief in a one to one correspondence between theory and reality. What makes the resultant knowledge "objective" is, perhaps even more than the ostensible split between subject and object, the separation within ourselves on which it is based. Scientific knowledge is made objective first by being dissociated from other modes of knowledge which are affectively tinged and hence tainted, and second, by being transcendentally wedded to the objects of nature. This felicitous marriage between the scientific mind and nature is consummated, not by worldly intercourse, but by a form of direct communion with nature, or with God, for which the scientific mind is uniquely, and unquestionedly, equipped.[2]

The loneliness which others might find in a world in which subject and object are split apart is compensated, for the scientist, by his special access to the transcendent link between the two. Impulses implicit in these two components of objectivism, however logically conflictual, finds exquisite resolution in the classical Newtonian world view. Their intermingling confounds our efforts at sorting out the dual aims of power and transcendence evident in the scientific endeavor; it leads simultaneously to the romantic view of the scientist as religious mystic—celibate, austere, and removed from the world of the senses, and to the technological view of science as dedicated to mastery, control, and the domination of nature. It would seem that an analysis of their primitive sources might permit an appreciation of the ways in which these impulses collaborate to produce the character—collectively and individually—of the scientific enterprise. The possibilities of such an analysis tease the imagination, and I will have a little more to say about this later. But first, however, I want to try to spell out the ways in which these two components have evolved under the impact of quantum mechanics.

Physical theory provides a description of reality by designating the state of the system, a system being a single particle or group of particles. In classical theory, the state of a system is a point in phase space, i.e., the position and momentum of the particle (or particles). Quantum mechanics precludes such a specification, and offers in its stead a vector in Hilbert space, or the wave function, which contains the maximal information possible about the state of the system. It is the character of this description which generates the familiar concepts of wave-particle duality, complementarity and uncertainty. The wave function is not a point in space, but rather a distribution of points. It does not in general prescribe a definite value for the position, momentum, or, for that matter, any observable of the system, but only a "probability amplitude." Furthermore, the more precise a specification provided by the wave function for one observable, e.g., position, the less precise its specification for the complementary observable, e.g., momentum. Questions of interpretation arise out of the need to articulate the relation between this description and the actual system. In classical theory, little difficulty arose from regarding the state of system as simultaneously and equally an attribute of the theoretical description and of the system itself. In quantum mechanics, however, the very character of the description provided by theory makes it extremely difficult, if not impossible, to maintain this identification. In spite of the fact that the wave function of a system, prior to measurement, fails to prescribe a definite value of the observable being measured, any measurement invariably yields a definite value. That is, upon looking, the system is always found to have a definite position, momentum, spin, etc. The state of the system is quite definite after the measurement, with respect to the variable being measured, however indefinite it may have been before, The wave function is said to have "collapsed." It is the need to interpret this statement which generates the major problems and confusions that surround the debates over quantum mechanics.

One rather dramatic form in which such problems find expression is that of Schrödinger's cat, whose hypothetical death is triggered, Rube Goldberg style, by the decay of a radioactive nucleus. The time of decay, and hence the time at which the cat is killed, is indeterminate; theory can provide no more than a "probability amplitude" for decay at any particular time. When enough time has elapsed to yield a probability of decay of one half, the wave function for the system will be a "superposition" of states in which the live cat and dead cat are mixed in equal proportions. The ostensible paradox emerges from the evident fact that any particular cat must be either alive or dead, while the wave function represents both. Schematically, one can point to two classes of errors which persist, in varying degrees and combinations, in the effort to resolve this paradox.

The first error resides in what can be called the statistical interpretation, in which it is asserted that the state of the system is a description only of a conceptual ensemble of similarly prepared systems; no knowledge about an individual system is claimed, or, indeed, is considered possible. Any particular cat of Schrödinger's is, at any time, either alive or dead. The wave function, however, describes only an ensemble of such cats. Its "collapse" is viewed as being no different from the "collapse" of any probability distribution function in the face of new knowledge. This view, while avoiding many pitfalls which other views leave themselves open to, permits the retention of the classical view of the particle as having a well defined position and momentum (and hence a classical trajectory), albeit unknowable. That is, the objectifiability of the system is maintained, while its knowability is sacrificed.[3] The particle is allowed to retain its objectlike, classical reality on the condition that our claim to the possibility of a one to one mapping of that reality onto our theoretical constructs is abandoned. The necessity of rooting the correspondence between theory and reality in the empirical, experiential process of observation is acknowledged, and results of that experience force us to give up our prior belief that the fit can be made perfect.

This is a radical posture insofar as it represents a decisive developmental step beyond the belief in the existence of a direct correspondence unmediated by actual experience—a belief which I think ought properly be called magical. It is not radical enough insofar as it fails to give up the picture of reality which had emerged under the classical regime. In this interpretation, the attribution of wavelike properties to the particles themselves is, quite correctly, understood to be a mistake. The wavelike properties are acknowledged to belong to, i.e., emerge from the process of observation. To quote one physicist,[4] "Students should not be taught to doubt that electrons, protons, and the like are particles . . . the wave cannot be observed in any way than by observing particles." What is not acknowledged here is that the same statement can be and must be made of its particlelike properties. They too emerge only from the process of observation. In giving up the comfortable belief that the wave function provides a theoretical description of an individual system, the adherence to the classical picture of that system leads to the extreme statement that quantum mechanics has nothing at all to say about the individual system (see, for example, Ref. 5). It is in this last statement that the inadequacy of the statistical interpretation specifically resides. The wave function, or quantum-mechanical state represents a picture not of the individual system itself, but of the associated processes of preparation and detection of either an individual system or an ensemble of systems, and is capable of yielding quite definite statements about an individual system. This the statistical interpretation does not account for.[6]

The second, and far more common, kind of error that permeates interpretations of quantum mechanics lies in attributing a kind of objective, material reality to the wave function itself. This mistake resides implicitly in all views which claim that the quantum-mechanical state constitutes a complete and sive exhaustive description of the system. It expresses itself in statements which assert that a system "has state 'psi,' " or "there exists a state or wave function," implying that in determing that state, one is measuring something which is an intrinsic or objective property of the system rather than of the measurement process itself. This posture has a long history, dating from Schrödinger's most primitive view of the wave function as a kind of material distribution of the particle. It lies behind the conception of the particle or system as actually possessing wavelike properties, and leads to seeing the "collapse" of the wave function as a real paradox. Contained in the surprise that the wave function can "collapse" from a distribution of values to a particular value is the belief that a system itself undergoes, in the process, a similar collapse. If so, the question of how this is accomplished is indeed a difficult one, and has understandably plagued discussions of quantum mechanics since its inception.

Many authors have suggested that it is the act of observation which "causes" the collapse of the wave function, thus inviting further debate about what it is in the act of observation which triggers this reduction. Wigner has gone so far as to assert that it is the very act of knowing which exerts what is now perceived as a physical effect on the system, forcing it into a state with definite position, momentum, or spin. He argues that, since it is well known in physics that to every action there is a reaction, it would be unreasonable to suppose that phenomena can exert an influence on our consciousness without our consciousness in turn exerting an effect on the phenomena. Thus Schrödinger's cat would be induced into a state of being definitely alive or dead by the very act of knowing.

This is the most extreme of a range of positions which are sometimes called the "subjective" interpretations of quantum mechanics—all loosely associated with the "Copenhagen Interpretation." What is meant by the label "subjective" is that in these interpretations, the classical conviction in the independence of the object from the subject is given up. Experience demonstrates the failure of the classical dichotomy; subject and object are inevitably, however subtly, intertwined. So far so good. The difficulties arise however in the attempt to overestimate our capacity to describe that interaction. That is, being unwilling to acknowledge aspects of reality not contained in the theoretical description, it is the system itself, e.g., the electron, which must bend, twist, or collapse in response to our observation. Such a system cannot be a classical particle; classical particles are neither "spread out," nor do they "collapse." We give up the classical picture, but impose on reality the picture of our theoretical description, saying, implicitly, that the system *is* this peculiar object, the wave function. In short, the subject-object dichotomy is relinquished, but the attachment to a one-to-one correspondence between reality and theory is not. In these interpretations, belief in the "knowability" of nature is retained, at the expense of its "objectifiability." Reality then, of necessity, takes on rather bizarre properties in this effort to make it conform to theory, leaving very few quite content.

In an effort out of this quagmire, more and more outlandish alternatives are proposed. As with the child caught between cognitive paradigms, the ingenuity which physicists have displayed is quite impressive. Thus, for example, a number of physicists have expressed enthusiasm for a resolution called "The Many Worlds Interpretation of Quantum Mechanics," in which the universe is seen as continually splitting into a multitude of mutually unobservable but equally real worlds. In each world, measurement yields a definite result. Schrödinger's cat is unequivocally alive in some, dead in others. All that remains equivocal is in which world we shall find ourselves. This interpretation demonstrates remarkable ingenuity in that it manages to retain both the confidence in the object reality of the system, and its literal correspondence with theory. Of course, a price has been paid—namely the price of seriousness.

Finally, all of this confusion can be avoided by dismissing the questions altogether. The strong positivist ethos surrounding contemporary science makes it possible for some, perhaps most physicists, to limit the definition of reality to the body of theoretical and empirical knowledge at our disposal, and to declare as meaningless all questions about the actual nature of the systems being studied, and our relation to those systems. Without embarking on a critique of this position, I wish only to point out what is fairly obvious, namely that it provides an extraordinarily convenient cover under which all sorts of prior beliefs about the world and its relation to science can, and do, subterraneously reside. It is too bad that we do not permit the child similar license to respond to Piaget's telling questions—questions that cannot be handled within an existing cognitive paradigm—by saying simply, "Your questions are meaningless."

At this point it must be asked why the classical paradigm is so difficult to give up *in toto.* Piaget attributes cognitive repression to the familiarity and success of older, established structures, and no doubt he is at least partly right. Certainly, the classical tenets of science have proved extraordinarily successful, and continue, in most areas of science, to do so.

It seems, however, that the confusion that has for so long been evidenced in discussions about quantum mechanics, and the intense emotion that such discussions can evoke, suggest that more is at stake than simply the comfort and success of an older paradigm. The great weakness of Piaget's developmental system is his failure to include any consideration of the impact of affective components on the developmental process. Egocentricity, omnipotence, and object permanence are all terms that have profound meaning in the domain of affective relations as well as cognitive relations. While some attempt has been made to integrate the psychoanalytic understanding of affective development with Piaget's understanding of cognitive development, particularly in the earliest stages of development, this remains a task largely undone. A few comments may nevertheless be in order.

We know from both Piaget and from psychoanalysis that the capacity for objective thought and perception is not inborn, but, rather, is acquired as part of the long and painful struggle for psychic autonomy—a state never entirely free from ambiguity and tension. The internal pressure to delineate self from other—a pressure exacerbated by the historical emphasis on ego autonomy—leaves us acutely vulnerable to anxiety about wishes or experiences which might threaten that delineation. We know further that such anxiety can sometimes be allayed by the imposition of an excessively delineated structure on one's emotional and cognitive environment. It would seem, therefore, that objectification in science may serve a related function—that the severance of subject from object, as well as the insistence on the premise that science is affect-free may derive in part from a heavily affect-laden motive for separateness and may serve to buttress a sense of autonomy. If so, then the continuing adherence to the belief in the objectifiability of nature would be assisted by the emotional functions served by this belief.[7]

Similarly, the attachment to the premise that nature is "knowable" can also be viewed in psychological terms. The ideal of a perfect congruence between us as knowers and an objective reality to be known is an ideal that is strikingly reminiscent of other ideas—ubiquitous among children—which we call magical. It represents a continuing belief in omniscience, now translated out of the domain of magic into the domain of science. Based on a vision of transcendent union with nature, it satisfies a primitive need for connection denied in another realm. As such, it mitigates against the acceptance of a more realistic, more mature, and more humble relation to the world in which the boundaries between subject and object are acknowledged to be never quite rigid, and in which knowledge, of any sort, is never quite total.

Quantum mechanics provides eloquent testimony for the need to relinquish both of these premises; however successful they have been in the past, they are no longer adequate. Yet even that testimony remains obscured by interpretations which implicitly attempt to retain some residue of the classical paradigm. Each of the two dominant schools of interpretation—the statistical and the Copenhagen—suffers from inadequacies which are evident to proponents of the other, and debate between the two continues. The failure to reach a resolution of this debate reflects the difficulties even quantum physicists have in completely relinquishing some adherence to at least one of the two basic premises of classical physics—the objectifiability and knowability of nature. The vision implicit in quantum mechanics still awaits representation in a cognitive paradigm yet more radical than the conventional interpretations have offered us.

[1]J. Piaget, J. Am. Psa. Assn. **21**, 249 (1973).

[2]Newton, e.g., was sometimes quite explicit in articulating the consonance between scientific thought and God's "Sensorium": "... there is a Being incorporeal, living, intelligent, omnipresent who in infinite space, as it were in his sensory, sees things intimately ... of which things the images only ... are there seen and beheld by that which in us perceives and thinks." (Opticks, 3rd ed. London 1921, p. 344.)

[3]"Objectifiable," here and elsewhere, means *both* objective, i.e. independent of our cognizance, *and* objectlike, hence having a well-defined position in space and time. As remarked earlier, these two meanings are almost always conjoined.

[4]N. F. Mott, Contemp. Phys. **5**, 401 (1964).

[5]A. Peres, Am. J. Phys. **42**, 886 (1974).

[6]Although not generally realized, it is in fact possible to formulate quantum mechanics entirely in terms of yes-no judgements, without ever making reference to probabilities [see, e.g., D. Finkelstein, Trans. N.Y. Acad. Sci. 621 (1964)].

[7]For further elaboration of this point, see E. F. Keller, Psychoanal. Contemp. Thought **1**, 409 (1978).