Quantum Mechanics and the Philosophy of Alfred North Whitehead

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Introduction

This chapter is intended to provide a brief overview of the synthesis developed over the course of the book. As a result, it occasionally incorporates certain concepts and terminology that have yet to be introduced. Since this book was written for readers with varying familiarity with quantum mechanics and Whitehead's philosophy—including no familiarity with either—readers with some knowledge of both should begin with this chapter, whereas those who need familiarization with the subjects might skip ahead to chapter 2.

The attempted correlation of quantum mechanics and Whitehead's cosmological scheme—or any philosophical scheme, for that matter—is an endeavor to be expected of both philosophers and physicists discomfited by the various "paradoxical" conceptual innovations inherent in quantum mechanics when interpreted according to the classical ontology of mechanistic materialism. That various proposed correlations of quantum mechanics and Whitehead's cosmology have come from both philosophers and physicists, then, should not surprise, nor should their respective emphases of approach: The philosophers tend to depict the physical side of the correlation in overly broad strokes in order to avoid the infamously complicated concepts and terminology inherent in quantum mechanics, and the physicists, who prefer to avoid the infamously complicated concepts and terminology inherent in Whiteheadian cosmology, tend to depict his metaphysical scheme in similarly broad strokes.

Some of the proposals made thus far—those suggested by Abner Shimony,1 Henry Folse,2 and George Lucas,3 for example—have proven useful in establishing an initial dialogue; but they have tended to break down once a certain level of detail is approached, on either the physics side or the philosophy side. With respect to the latter, the reason lies not in any failure by philosophers to comprehend quantum mechanics adequately, but rather with the advocacy
of certain popular interpretations of quantum mechanics founded upon and inspired by concepts wholly incompatible with the Whiteheadian cosmological scheme. These incompatibilities are most easily evinced by the extent to which a particular interpretation of quantum mechanics fails to meet the four desiderata Whitehead requires of his and any philosophical interpretation of experience—physical, microphysical, or otherwise. Such an interpretation, writes Whitehead, should be: (i) \textit{coherent}, in the sense that its fundamental concepts are mutually implicative and thus incapable of abstraction from each other; (ii) \textit{logical}, in the ordinary sense of the word, as regards consistency, lack of contradiction, and the like; (iii) \textit{applicable}, meaning that the interpretation must apply to certain types of experience; (iv) \textit{adequate}, in the sense that there are no types of experience conceivable that would be incapable of accommodation by the interpretation.\footnote{Thus, for example, attempts to demonstrate the compatibility of Bohr's principle of complementarity and Whiteheadian metaphysics, though perhaps useful in terms of higher-order epistemological issues, fails for lack of coherence at the most fundamental level, the very level for which it was intended. Bohr's two complementary characterizations of our experiences of nature—classical and quantum—are not mutually implicative, and this is the very point of complementarity. Henry Folse suggests that a correlation of Bohr's interpretation of quantum mechanics and Whitehead's philosophy is in order, primarily because of the repudiation of fundamental mechanistic materialism common to both; "however," Folse admonishes, "the fate of any potential alliance is in jeopardy so long as current discussions of the subject insists on concentrating on the fine points of quantum interpretation rather than its broader more general ramifications." He continues:}

\begin{quote}
Quite naturally there are so many aspects of the philosophy of organism which find no counterpart in the philosophical extrapolations of the Copenhagen Interpretation. . . . There is no reference to the equivalents of "feeling," "satisfaction," or "conceptual prehension." Yet Whitehead would have anticipated this, for the physicists' interpretation of theory is based on a very small segment of experience; Whitehead's system aims at far greater compass.\footnote{The difficulty is that concepts like "feeling," "satisfaction," and "conceptual prehension" are fundamental to Whiteheadian meta-}

\end{quote}
physics. They are not higher-order abstractions that should be, or even can be, ignored whenever applied to the specialized interpretation of physical experiences. But aside from specific correlatives in the physical sciences for the terms “feeling,” “satisfaction,” and “conceptual prehension,” which Whitehead does, in fact, specify, the incompatibility of Bohr’s interpretation of quantum mechanics and Whitehead’s metaphysical scheme lies most fundamentally in the simple failure of Bohr’s principle of complementarity to meet the desideratum of ontological coherence.

Similar attempts to ally Whitehead’s cosmology with David Bohm’s nonlocal hidden variables interpretation of quantum mechanics fail for the same reason, despite the focus upon certain significant compatibilities, such as that of (i) Bohm’s “implicate order” pertaining to the etherlike field of all actualities in the universe, correlate with (ii) the analogous concept of necessarily and mutually interrelated actualities in Whitehead’s scheme, as well as the repudiation of fundamental classical “extended substance” common to both. In Bohm’s scheme, however, the repudiation of fundamental substance (Bohm’s particles, though concrete, are more akin to Einstein’s “point-instants” and Whitehead’s “actual occasions” than extended substance) is not a repudiation of deterministic, mechanistic materialism, as it is in Whitehead’s ontology. Bohm’s fundamentally deterministic “implicate order” inherent in the field of all actualities entails symmetrical and therefore purely deterministic relations among these actualities.

Insofar as these relations remain hidden within the deep realm of Bohm’s “implicate order,” our participation in this order is restricted to manifold epistemically limited observational contexts. Bohm suggests that because of this, his theory in no way vitiates conceptions of freedom, creativity, novelty, and so forth—principles central to Whiteheadian metaphysics. However, given that the fundamental implicate order of the universe is deterministic, hidden though this order may be, it is difficult to see how freedom grounded in epistemic ambiguity can be thought to be as significant as freedom grounded in an ontological principle—even if our finite observational contexts all but guarantee such ambiguity. Bohm writes:

As long as we restrict ourselves to some finite structures of this kind, however extended and deep they may be, then there is no question of
complete determinism. Each context has a certain ambiguity, which may, in part, be removed by combination with and inclusion within other contexts. . . . If we were to remove all ambiguity and uncertainty, however, creativity would no longer be possible.7

An ontologically significant principle of freedom from determinacy requires an asymmetrical temporal modality and its associated logical order, where the past is settled and closed and the future is open—a temporality that is irreversible. This is a key feature of Whitehead’s metaphysics. Though Bohm’s implicate order is fundamentally temporally symmetrical and deterministic, he suggests that there is some similarity between Whitehead’s process of concrescence and the quantum mechanical relationships among the actualities of his “implicate order” cosmology. “A key difference,” he notes, is that these relationships are grounded in the deeper, “timeless” implicate order that is common to all these moments. . . . It is this implicate “timeless” ground that is the basis of the oneness of the entire creative act. In this ground, the projection operator $P_n$, the earlier ones such as $P_{n-1}$, and the later ones such as $P_{n+1}$ all interpenetrate, while yet remaining distinct (as represented by their invariant algebraic structures).8

Epistemic uncertainty as to the specifications of most of these relations manifests itself as the familiar, temporally asymmetrical “explicit order” characterizing our experiences, such that temporal priority appears reflective of logical priority. This reflection is evinced, for example, by the one-way direction of time associated with the laws of thermodynamics. But if one could peer through the epistemic veil of this temporal asymmetry—if one could perceive the implicate order of hidden variables and its associated “pre-space”—then the fundamentally symmetrical relationship among past, present, and future would be revealed. Bohm writes:

If it were possible for consciousness somehow to reach a very deep level, for example, that of pre-space or beyond, then all “nows” would not only be similar—they would all be one and essentially the same. One could say that in its inward depths now is eternity, while in its outward features each “now” is different from the others. (But eternity means the depths of the implicate order, not the whole of the successive moments of time.)9

But since temporal priority is merely epistemically significant by such an interpretation, it is unclear how it might have any significant
correlation with an ontologically significant logical priority. As mentioned earlier, such a gulf between the contingent and the necessary has its roots in the problem of χωρισμός, or "separation" of necessary forms from contingent facts in Plato’s metaphysics. It is a problem central to many interpretations of quantum mechanics, and also to interpretations of the special and general theories of relativity—the latter with respect to the relationship between the formal geometrical character of spacetime and the facts constitutive of spacetime. In the general theory of relativity, Einstein bridges Plato’s χωρισμός by deriving the formal geometry of spacetime from the events themselves; this approach to χωρισμός, then, has a certain compatibility with the hidden variables interpretations of quantum mechanics discussed earlier. (The close relationship between quantum mechanics and theories of spatiotemporal extension is addressed at length in chapter 5.)

In the Whiteheadian cosmology, the integration of (i) the asymmetrical, logical modal relations among facts and (ii) the symmetrical, relativistic modal relations among spatiotemporal forms of facts, is a function of the fundamental dipolarity of actualities. But in Whitehead’s scheme, the asymmetrical, logical ordering among actualities as genetically related, serially ordered becomings, is, in one sense, the fundamental order upon which their symmetrical, relativistic spatiotemporal ordering is predicated. The existence of facts is thus, by the requirement of logic, necessarily prior to their spatiotemporal ordering in Whitehead’s metaphysical scheme. But Bohm’s hidden variables interpretation entails the opposite—that it is the symmetrical, deterministic relations among actualities which are fundamental to the asymmetrical—and by his interpretation, ontologically insignificant—logical ordering of the actualities themselves. Thus, the irreversibility of thermodynamic processes, for example, is by Bohm’s interpretation merely a statistical epistemic artifact of an underlying purely deterministic, symmetrical, “implicate” order.

Bohm and his colleague B. J. Hiley illustrate this fundamental deterministic symmetry of the implicate order by describing the workings of a particular experimental apparatus:

This device consists of two concentric glass cylinders; the outer cylinder is fixed, while the inner one is made to rotate slowly about its axis. In between the cylinders there is a viscous fluid, such as glycerine, and
into this fluid is inserted a droplet of insoluble ink. Let us now con­
sider what happens to a small element of fluid as its inner radius
moves faster than its outer radius. This element is slowly drawn out
into a finer and finer thread. If there is ink in this element it will move
with the fluid and will be drawn out together with it. What actually
happens is that eventually the thread becomes so fine that the ink
becomes invisible. However, if the inner cylinder is turned in the re­
verse direction, the parts of this thread will retrace their steps. (Be­
cause the viscosity is so high, diffusion can be neglected.) Inevitably
the whole thread comes together to reform the ink droplet and the
latter suddenly emerges into view. If we continue to turn the cylinder
in the same direction, it will be drawn out and become invisible once
again.

When the ink droplet is drawn out, one is able to see no visible
order in the fluid. Yet evidently there must be some order there since
an arbitrary distribution of ink particles would not come back to a
droplet. One can say that in some sense the ink droplet has been en­
folded into the glycerine, from which it unfolds when the movement
of the cylinder is reversed.

Of course if one were to analyse the movements of the ink particles
in full detail, one would always see them following trajectories and
therefore one could say that fundamentally the movement is de­
scribed in an explicate order. Nevertheless within the context under
discussion in which our perception does not follow the particles, we
may say this device gives us an illustrative example of the implicate
order. And from this we may be able to obtain some insight into how
this order could be defined and developed.\textsuperscript{10}

Bohm and Hiley go on to suggest that this implicate order “con­
tains explicate suborders as aspects which are particular cases of the
general notion of implicate order. In this way we clarify our earlier
statement that the implicate order is general and necessary, while
explicate orders are particular and contingent cases of this.”\textsuperscript{11}

The predication of actualities upon the relativistic spatiotemporal
relations among actualities—the predication of facts upon their im­
plicate ordering—similarly manifests itself in popular quantum cos-
mogonic models such as those proposed by Stephen Hawking and
James Hartle, wherein a vacuous spacetime is purported to evolve
quantum mechanically from a void of pure potentiality—
potentiality somehow abstracted from actuality. Such a void, often
termed a “quantum vacuum” or “quantum foam,” is a fundamen-
tally incoherent construction, given that the concept of actuality is necessarily presupposed by the concept of potentiality, such that the latter cannot be abstracted from the former. This is both a logical requirement and a requirement of quantum mechanics, which describes the evolution of actual facts and their associated potentia—not the evolution of vacuous potentia into actuality.

These conceptual impediments to the fundamental logic and coherence of the preceding interpretations of quantum mechanics all stem from a common source—the attempt to use quantum mechanics to account for the existence of actualities, when quantum mechanics both presupposes and anticipates their existence. This presupposition and anticipation is clearly reflected in the mathematical concept of probability, which—as it pertains to the termination of a quantum mechanical measurement in a matrix of probable actualities rather than a determined, unique actuality—is a quantifiable propensity that a presupposed fact will evolve to become a quantifiably anticipated novel fact. (In quantum mechanics, and in Whiteheadian metaphysics, the anticipated unique novel fact is both subsequent to and consequent of the evolution.) Any interpretation of quantum mechanics that meets the desideratum of logic, then, cannot include a quantum mechanical account of the existence of actualities, which are both presupposed and anticipated by the mechanics.

The two interpretations of quantum mechanics briefly described earlier—those of Bohr and Bohm—were both born of inductive philosophical generalizations, which is to be expected of scientific theories to some degree. But these generalizations, each in its own way, fail to meet one or more of the Whiteheadian desiderata for a sound philosophical scheme by which we can coherently and logically interpret our experiences of the physical world. “The only logical conclusion to be drawn, when a contradiction issues from a train of reasoning,” writes Whitehead, “is that at least one of the premises involved in the inference is false.” As regards these two interpretations of quantum mechanics, the culprit premise is the concept of fundamental mechanistic materialism. Bohr attempts to salvage this concept by draining it, and its complementary quantum theoretical conception of nature, of all ontological significance; the facts of objective nature are thus permanently veiled to the extent that we must replace the notion of “objective facts of nature” with public
coordinations of our experiences of nature.\textsuperscript{13} And Bohm attempts to salvage the primacy of mechanistic materialism by resorting to a similar veil, such that the \textit{apparent} openness of the future by its asymmetrical relations with the facts of the past—as related to the \textit{apparent} indeterminacy of quantum mechanics, for example—is merely a statistical artifact of an epistemic handicap that prevents us from observing and specifying the ether of “hidden variables.” This ether, for Bohm, constitutes the implicit, underlying universe of fundamentally symmetrically related facts—that is, a fundamentally deterministic universe.

In contrast, however, recent years have brought the development of a family of interpretations of quantum mechanics formulated in part as a response to these difficulties. This family of interpretations uses only the orthodox “Copenhagen” quantum theoretical formalism, but abstracted from the philosophical sanctions placed by Bohr upon its proper interpretation. Instead, it begins with a decidedly nonclassical concept, suggested by Heisenberg (and resurrected from Aristotle), that actuality and potentiality constitute two fundamental species of reality. This new characterization of potentia as ontologically significant by itself does much to eliminate the infamous paradoxes of quantum mechanics, as Heisenberg points out,\textsuperscript{14} and it is an acute example of the importance, commended by Whitehead, of imaginative generalization in the construction of a sound philosophical scheme; for Heisenberg’s characterization of potentia as ontologically significant picks up where the inductive generalizations from classical mechanics failed in their attempted logical and coherent application to the quantum theory. And coupled with the explicit acknowledgment that quantum mechanics cannot be used to account for the existence of actualities, which it necessarily presupposes and anticipates, these two concepts—actuality and potentiality as fundamental species of reality—form the cornerstone of this new family of interpretations. These interpretations characterize quantum mechanics not as a means of describing the actualization of potentia (for the terminal actuality, like the antecedent actuality, is presupposed by the mechanics), but rather as a means of describing the \textit{valuation} of potentia. And as regards the central role of mathematics in these quantum mechanical valuations, Whitehead clearly believes that the success of specific mathematical concepts upon which the quantum theory is founded—probability, tensors, and ma-
trices, to name a few—derives from their origination in the “imaginative impulse,” controlled by the requirements of logic and coherence: “It is a remarkable characteristic of the history of thought that branches of mathematics, developed under the pure imaginative impulse, thus controlled, finally receive their important application. Time may be wanted. Conic sections had to wait for 1800 years. In more recent years, the theory of probability, the theory of tensors, the theory of matrices are cases in point.”

And as the imaginative impulse was central to the formulation of the mathematical concepts and formalism of quantum mechanics, so would it be to the formulation of a coherent and logical interpretation of quantum mechanics. Thus, from the imaginative conception of ontologically significant potentia, the speculative generalization is further expanded to include three more concepts—each of which is presupposed by the quantum formalism: (i) that actualities evolve to become novel actualities, forming historical routes of actualities, and it is their associated potentia which mediate this evolution from actuality to actuality; (ii) that the evolution of any actuality somehow entails relations with all actualities by virtue of the closed system, required by the Schrödinger equation, comprising all actualities; (iii) that these necessary relations, when relative to a single evolution, require a process of negative selection whereby the coherent multiplicity of relations is reduced into a set of decoherent, probability-valuated, mutually exclusive and exhaustive, potential novel integrations, such that superpositions of mutually interfering potentia incapable of integration are eliminated. This process of negative selection guarantees that histories of actualities are mutually consistent (that is, in compliance with the logical principles of non-contradiction and the excluded middle), such that the novelty of the future does not vitiate the actuality of the past.

This process of negative selection describes what is referred to as the “decoherence effect,” and the family of interpretations referred to earlier consists of those that agree upon the ontological significance of this process, as well as those related concepts discussed earlier. Many notable theorists, including Robert Griffiths, Wojciech Zurek, Murray Gell-Mann, and Roland Omnès, among several others, have demonstrated that the interrelations among all facts—those belonging to a measured system, a measuring apparatus, and the environment englobing them—play a crucial conceptual and mechanical role in the elimination of superpositions of nonsensical, in-
terfering potentia (and potential histories) via negative selection and the resulting decoherence effect. Though the proposals of each of these thinkers differ somewhat, they all emphasize the importance of this negative selection process. According to Žurek’s Environmental Superselection interpretation, for example, “Decoherence results from a negative selection process that dynamically eliminates non-classical [i.e., mutually interfering and thus incompatible] states.”\(^{16}\) Žurek, like many physicists who believe in the central importance of this process of negative selection, maintains that decoherence is a consequence of the universe’s role as the only truly closed system, which, put another way, guarantees the ineluctable “openness” of every subsystem within it. “This consequence of openness is critical in the interpretation of quantum theory,” Žurek continues, “but seems to have gone unnoticed for a long time.”\(^{17}\)

The quantum mechanical evolution of the state of a system is thus characterized as the valuation of potential novel facts, and potential novel histories of facts, as the evolution proceeds relative to the historical route of actualities constitutive of itself and its universe. The valuations of potentia terminal of this quantum mechanical evolution are describable as a matrix of probabilities, such that they are mutually exclusive and exhaustive—that is, additive in the usual sense. Also, as probabilities, the actualities of the past are presupposed, and a unique actuality terminal of the evolution is similarly presupposed and anticipated. It is understood, then, that this final phase of the evolution—the unitary reduction to a single actuality—lies beyond the descriptive scope of quantum mechanics.

The evolutionary valuation of potentia in quantum mechanics can be correlated phase by phase, and concept by concept, with Whitehead’s metaphysical scheme, such that the former can be characterized as the fundamental physical exemplification of the latter. Both entail that a world of mutually interrelated facts (Whitehead’s “actual occasions”) is presupposed and anticipated in the evolution of each novel fact, and that the inclusion of these facts of relatedness (Whitehead’s “prehensions” of facts as “data”) in the act of measurement, by these necessary mutual interrelations, somehow entails the following: (i) all other facts and their associated potentia-either in their inclusion in the specification, or their necessary exclusion from the specification. This requirement is reflected in Whitehead’s “Principle of Relativity” and his “Ontological Principle,” and in
quantum mechanics by the Schrödinger equation's exclusive applicability to closed systems, with the universe being the only such system. The exclusions relate to the process of negative selection productive of the decoherence effect, to be discussed presently, and Whitehead refers to these eliminations as "negative prehensions." Their form and function with respect to environmental degrees of freedom are identical to those related to the process of decoherence; (ii) the evolution of the system of all facts into a novel fact—namely, a maximal specification (the "state" specification) of the relevant facts (those not excluded by decoherence or "negatively prehended" in Whitehead's terminology). State specification—the maximal specification of many facts via the necessary exclusion of some facts—thus entails the evolution of a novel fact—namely, a unification of the facts specified; and (iii) the requirement that this evolution proceed relative to a given fact, typically belonging to a particular subsystem of facts. In quantum mechanics, these are, respectively, the "indexical eventuality" and the "measuring apparatus"; Whitehead's equivalent conceptions are, respectively, the "prehending subject" and its "nexus"—that is, the system of actualities to which the subject belongs. This requirement that state evolution (Whiteheadian "concrescence") always proceed relative to a particular fact or system of facts is given in Whitehead's "Ontological Principle" and "Category of Subjective Unity"; their correlates in quantum mechanics—the necessary relation of a state evolution to some preferred basis characteristic of the measuring apparatus—has often been misapprehended as a principle of sheer subjectivity, the source of the familiar lamentations that quantum mechanics destroys the objective reality of the world.

Measurement or state specification thus entails, at its heart, the anticipated actualization (concrescence) of one novel potential fact/entity from a matrix of many valuated potential facts/entities that themselves arise from antecedent facts (data); and it is understood that the quantum mechanical description of this evolution terminates in this matrix of probability valuations, anticipative of a final unitary reduction to a single actuality. Ultimately, then, concrescence/state evolution is a unitary evolution, from actualities to unique actuality. But when analyzed into subphases, both concrescence and quantum mechanical state evolution are more fundamentally nonunitary evolutions, analogous to von Neumann's conception
of quantum mechanics as most fundamentally a nonunitary state evolution productive of an anticipated unitary reduction.\textsuperscript{18} It is an evolution from (i) a multiplicity—the actual many—to (ii) a matrix of potential “formal” (in the sense of applying a “form” to the facts) integrations or unifications of the many (Whitehead’s term is propositional “transmutations” of the many—a specialized kind of “subjective form”—and he also groups these into “matrices”\textsuperscript{19}). Each of these potential integrations is described in quantum mechanics as a projection of a vector representing the actual, evolving multiplicity of facts onto a vector representing a potential “formally integrated” outcome state (\textit{eigenstate}). The Whiteheadian analog of the actual multiplicity’s “projection” onto a potential integration is “ingression”—where a potential formal integration arises from the ingression of a specific “potentiality of definiteness”\textsuperscript{20} via a “conceptual prehension” of that specific potentiality (Whitehead also refers to these potential facts as “eternal objects” and explicitly equates the two terms\textsuperscript{21}). But whereas in quantum mechanics, the state vector representing the actual multiplicity of facts is projected onto the potential integration (the \textit{eigenvector} representing the eigenstate), in Whitehead’s scheme it is the latter which ingresses into the prehensions of the actual multiplicity. This difference reflects Whitehead’s concern with the origin of these potentia, for if they ingress into the evolution, then by his Ontological Principle they must be thought of as coming from somewhere. The eigenstate, or object of projection in quantum mechanics, is, in contrast, simply extant, and indeed, this is one of the infamous philosophical difficulties of quantum mechanics.

There are, furthermore, two important characteristics shared by both the quantum mechanical and Whiteheadian notions of potentia that should be noted here. First, there is a sense in which both are “pure” potentia, referent to no specific actualities. For Whitehead, “eternal objects are the pure potentials of the universe; and the actual entities differ from each other in their realization of potentials.”\textsuperscript{22} “An eternal object is always a potentiality for actual entities; but in itself, as conceptually felt, it is neutral as to the fact of its physical ingression in any particular actual entity of the temporal world.”\textsuperscript{23} In quantum mechanics, this pure potentiality is reflected in the fact that the state vector $|\Psi\rangle$ can be expressed as the sum of
an infinite number of vectors belonging to an infinite number of subspaces in an infinite number of dimensions, representing an infinite number of potential states or “potentialities of definiteness” referent to no specific actualities and potentially referent to all. Many of these are incapable of integration, forming nonsensical, interfering superpositions, and are eliminated as negative prehensions in a subsequent phase of concrescence.

Second, quantum mechanical potentia are also “inherited” from the facts constituting the initial state of the system (as well as the historical route of all antecedent states subsumed by the initial state) such that preferred bases in quantum mechanics are typically reproduced in the evolution from state to state. Similarly, in Whitehead’s scheme, antecedent facts, when prehended, are often “objectified” according to one of their own historical “potential forms of definiteness”—typically, the given potential forms that were antecedently actualized at some point in the historical route of occasions constituting the system measured.

An actual entity arises from decisions for it and by its very existence provides decisions for other actual entities which supersede it.24

Some conformation is necessary as a basis of vector transition, whereby the past is synthesized with the present. The one eternal object in its two-way function, as a determinant of the datum and as a determinant of the subjective form, is thus relational. . . . An eternal object when it has ingression through its function of objectifying the actual world, so as to present the datum for prehension, is functioning “datively.”25

Whitehead’s characterization of potentia as “relational,” then, is clearly exemplified by the manner in which potentia mediate the actuality of a measured system and the actuality of the outcome of the measurement—that is, the mediation between the initial and final system states.

The quantum mechanical state evolution/concrescence thus continues into its next phase: (iii) a reintegration of these integrations into a matrix of “qualified propositional” transmutations,26 involving a process of negative selection where “negative prehensions” of potentia incapable of further integration are eliminated. The potential unifications or propositional transmutations in this reduced matrix are each qualified by various valuations. Each potential transmuta-
tion relative to the indexical eventuality of the measuring apparatus (i.e., each potential outcome state relative to the apparatus and some prehending subject belonging to it) is thus a potential "form" into which the potential facts of the universe will ultimately evolve. Whitehead terms these "subjective forms." As applied to quantum mechanics, the term subjective refers to the fact that the "form" of each potential outcome state is reflected in the preferred basis relative to the indexical eventuality of the measuring apparatus (i.e., the prehending subject). Again, it is only the form that is thus subjective—for any number of different devices with different preferred bases could be used to measure a given system, and any number of different people with their own "mental preferred bases" could interpret (measure) the different readings of the different devices, and so on down the von Neumann chain of actualizations. The potential facts to which each subjective form pertains, however, are initially "given" by the objective facts constitutive of the world antecedent to the concrescence at hand. Thus, again, the "subjective form" of a preferred basis is in no way demonstrative of sheer subjectivity—that is, the evolution of novel facts as determined by a particular subject. It is, rather, demonstrative of the evolution of novel facts jointly determined by both the world of facts antecedent to the evolution and the character of the subject prehending this evolution by virtue of its inclusion in it. According to Whitehead’s "Ontological Principle,"

"Every condition to which the process of becoming conforms in any particular instance, has its reason either in the character of some actual entity in the actual world of that concrescence, or in the character of the subject which is in process of concrescence. . . ." 27

The actual world is the "objective content" of each new creation.28

The evolution thus proceeds to and terminates with what Whitehead terms the "satisfaction," which in quantum mechanical terms is described as (iv) the anticipated actualization of the final outcome state—that is, one subjective form from the reduced matrix of many subjective forms—in "satisfaction" of the probability valuations of the potential outcome states in the reduced matrix. In quantum mechanics, as in Whitehead’s model, this actualization is irrelevant and transparent apart from its function as a datum (fact) in a subsequent measurement, such that the "prehending subject" becomes
“prehended superject.” Again, this is simply because both Whitehead’s process of concrescence and quantum mechanics presuppose the existence of facts, and thus cannot account for them. For Whitehead, “satisfaction” entails “the notion of the ‘entity as concrete’ abstracted from the ‘process of concrescence’; it is the outcome separated from the process, thereby losing the actuality of the atomic entity, which is both process and outcome.”29 Thus, the probability valuations of quantum mechanics describe probabilities that a given potential outcome state will be actual upon observation—implying a subsequent evolution and an interminable evolution of such evolutions. Every fact or system of facts in quantum mechanics, then, subsumes and implies both an initial state and a final state; there can be no state specification S without reference, implicit or explicit, to S_initial and S_final. This is reflected in Whitehead’s scheme by referring to the “subject” as the “subject-superject”:

The “satisfaction” is the “superject” rather than the “substance” or the “subject.” It closes up the entity; and yet is the superject adding its character to the creativity whereby there is a becoming of entities superseding the one in question.30

An actual entity is to be conceived as both a subject presiding over its own immediacy of becoming, and a superject which is the atomic creature exercising its function of objective immortality. . . .31

It is a subject-superject, and neither half of this description can for a moment be lost sight of. . . .32

[The superject is that which] adds a determinate condition to the settlement for the future beyond itself.33

Thus, the process of concrescence is never terminated by actualization/satisfaction; it is, rather, both begun and concluded with it. The many facts and their associated potentia become one novel state (a novel fact), and are thus increased historically by one, so that, as Whitehead puts it, “the oneness of the universe, and the oneness of each element in the universe, repeat themselves to the crack of doom in the creative advance from creature to creature.”34 “The atomic actualities individually express the genetic unity of the universe. The world expands through recurrent unifications of itself, each, by the addition of itself, automatically recreating the multiplicity anew.”35

The specific phase-by-phase, concept-by-concept correlation of Whitehead’s cosmological scheme and the decoherence-based inter-
pretations of quantum mechanics—such that the latter are seen as a fundamental physical exemplification of the former—satisfies Whitehead's intention that his cosmological model be compatible with modern theoretical physics. Indeed, much of the development of the "Copenhagen" quantum formalism occurred contemporaneously with Whitehead's development of his cosmological scheme. Whitehead writes: "The general principles of physics are exactly what we should expect as a specific exemplification of the metaphysics required by the philosophy of organism." But it also satisfies the intention of the quantum theory's originators that it provide the fundamental physical characterization of nature—"die endgültige Physik"—an intention that can be fulfilled only within the context of a coherent, logical, applicable, and adequate ontological interpretation.

Ultimately, the test of the synthesis proposed herein, as is the case for any adventure in speculative philosophy, is to be found in renewed observation mediated by the metaphysical scheme both in areas of physics and in other areas as well—areas that, apart from the scheme, might have seemed entirely unrelated.

The success of the imaginative experiment is always to be tested by the applicability of its results beyond the restricted locus from which it originated. . . . The partially successful philosophic generalization will, if derived from physics, find applications in fields of experience beyond physics. It will enlighten observation in those remote fields, so that general principles can be discerned as in process of illustration, which in the absence of the imaginative generalization are obscured by their persistent exemplification.

The study of complex adaptive systems in nature, as one such application, has been the topic of a great deal of research and debate over the past several years, and has significant roots in attempts by several physicists to demonstrate that quantum mechanics describes such complexity at the most fundamental physical level. The "balanced complexity" described by Whitehead as the "subjective aim" governing the evolution of novel actuality in his cosmological scheme has a direct analog in the concept of "effective complexity"—also a balance of regularity (Whitehead's genetic "reproduction" of potentia) and diversity ("reversions" of potentia from the genetic regularity). Efforts have been made in the sciences to dis-
close the fundamental function and exemplification of effective complexity by referring to quantum mechanics, and the decoherence-based interpretations are particularly well suited to this task. The reasons are especially clear in the context of the Whiteheadian cosmology; for the decoherence effect is predicated upon the very notions of contrast of (i) diverse multiplicities of facts with (ii) regulated potential integrations of these facts (the regulation being a product, in part, of negative selection) into alternative, probability-valuated, mutually exclusive forms of definiteness.

The application of the decoherence-based interpretations of quantum mechanics to the study of complexity in nature, where the former is seen as a fundamental exemplification of the latter, is an area of inquiry significant not only to the philosophy of science but also, potentially, to the philosophy of religion. The contextualization of quantum mechanics in terms of the Whiteheadian cosmological scheme is commended here, for Whitehead's repudiation of fundamental mechanistic materialism is also a repudiation of its correlate characterization of the universe as a cold realm of mechanical accidents from which our purportedly illusory and sheerly subjective perceptions of purpose and meaning are, by certain views, thought to derive. In the words of Jacques Monod, the Nobel-laureate biochemist: "Man knows at last that he is alone in the universe's unfeeling immensity, out of which he emerged only by chance."40 In sharp contrast, by Whitehead's cosmology as exemplified by the decoherence interpretations of quantum mechanics, the universe is instead characterized as a fundamentally complex domain with an inherent aim toward an ideal balance of reproduction and reversion—a balance formative of a nurturing home for a seemingly infinitely large family of complex adaptive systems such as ourselves.

The usefulness of the synthesis of quantum mechanics and Whitehead's cosmology to conversations among philosophy, science, and religion is further demonstrated as it might apply to the role of God as primordial actuality in quantum mechanical cosmogonic models of creatio ex nihilo, such as the one proposed by Stephen Hawking and James Hartle41 mentioned earlier. Quantum mechanics describes the evolution of the state of a system of actualities always in terms of an initial state antecedent to the evolution, and a matrix of probable outcome states subsequent to and consequent of the evolution. Therefore, the application of quantum mechanics to the
description of any cosmogonic model—an inflationary universe model, for example—still requires a set of “initial conditions” or initial actualities at \( t = 0 \), when the evolution begins. In such an evolution, there must logically be, in other words, some actuality which evolves. Renaming these initial conditions “quantum vacuum” or “quantum foam” (equating them mathematically to the empty set), despite the intended connotations of these linguistic and mathematical terms, does nothing to relieve the theory of its logical obligation to presuppose the existence of facts antecedent to and subsequent to (and consequent of) a quantum mechanical evolution—whether this evolution describes the emission of an X ray from a black hole, or the emission of the universe from a black foam. For without these initial actualities, there can be no spacetime structure in which a quantum mechanical state evolution might operate. Hawking’s suggestion that it is a vacuous spacetime that first evolves quantum mechanically into actuality from sheer potentiality (i.e., from no initial actuality) defies the logically necessary predication of spacetime upon existence—the logically necessary predication of the ordering among actualities upon the actualities themselves.

But the Whiteheadian philosophy is likely to be useful in such conversations for another reason that has less to do with the facts of his philosophy than its form. For the spirit of speculative philosophy which animated both the development of Whitehead’s cosmological scheme and that of the decoherence-based interpretations of quantum mechanics will be equally useful to the rapidly widening conversation among philosophy, science, and religion. An appeal to the Whiteheadian spirit of speculative philosophy would do much to mediate and advance such conversations; for theories would, in this spirit, have the character of philosophic generalization hypothetically deduced relative to careful scientific observations, but coupled with the play of a free imagination and conditioned by the requirements of coherence and logic. The product of this creative amalgam, applied to subsequent observations, propels the process forward with the explicit understanding that the theories thereby created shall never achieve their perfect, final form—that the conversation shall never terminate.

The discussion that follows, because of the complexity inherent in each side of the synthesis, has been divided into two parts. Part I consists of an examination of the ontological innovations and conse-
quences of quantum mechanics; therein, the decoherence family of interpretations will be introduced and contrasted with a representative selection of other interpretations. Part II consists of the correlation of the ontological interpretation of quantum mechanics explored in Part I with Whitehead’s cosmological scheme—both “mechanically” in terms of the phases of concrescence exemplified by quantum mechanical state evolution, and conceptually, in terms of Whitehead’s nine Categoreal Obligations as fundamental principles presupposed and exemplified by the mechanics.

When considering this distinction between “mechanical” and “conceptual,” however, one must take care to avoid conflating the concept of “mechanism” with the concept of “materialism”—a conflation that lies at the heart of the conventional connotation of “mechanism.” Both quantum mechanics and Whiteheadian metaphysics describe a nondeterministic, nonmaterialistic process. But it is a mechanical process nonetheless, evinced in two aspects. First, it entails a realistic physics and metaphysics, grounded upon the objective actuality of the past; second, poten­tia are ontologically significant components of this process. They are integrated and reintegrated with other data into matrices of probability-valuated subjective forms according to a set of governing principles (Whitehead’s Categoreal Obligations, the various postulates of quantum mechanics, etc.)—principles capable of representation as rule-governed, mathematically describable constructions. Thus it is a nondeterministic, nonmaterialistic process that both Whiteheadian concrescence and quantum mechanical state evolution describe, both conceptually and mechanically; it is mechanism devoid of misplaced concreteness.

The intent of this book, then, is to suggest a narrow, phase-by-phase, concept-by-concept correlation of quantum mechanics and Whitehead’s metaphysical scheme—that is, a correlation that avoids any omissions of the conceptual and comparative phases of Whitehead’s “supplementary stage” of concrescence. Such omissions are often thought warranted when applying Whiteheadian philosophy to the physical sciences because of the presumed pertinence of these phases exclusively to conscious, high-order mental processes. This misplaced presumption might be due in part to Whitehead’s choice of the term “mental pole” as an alternative to the “supplementary stage” of concrescence, which for some readers unfortunately im-
plied a Cartesian connotation even though the repudiation of Cartesian mind-matter dualism is a fundamental principle of Whitehead’s metaphysical scheme.

By contrast, other attempts to correlate Whiteheadian metaphysics with quantum mechanics (particularly the information theoretic interpretations) have tended to elevate the operations of the mental pole to primacy. In these syntheses, the spatiotemporal coordinative operations of the physical pole (the “primary stage” of concrescence) are often either merged into the supplementary stage/mental pole, or they are done away with altogether. The intent of such approaches seems to be to render the spatiotemporal extensiveness of actualities and systems of actualities, as well as any theory describing such extensiveness (such as Einstein’s special and general theories of relativity), as mere abstractions derivable entirely from fundamental quantum events, in the same way that the concept of “material body” is so derivable in Whiteheadian metaphysics. By such interpretations, Whitehead’s “fallacy of misplaced concreteness” finds its exemplification not only in the conventional notion of “fundamental materiality” but also in the conventional notion of “fundamental extensiveness in spacetime.”

But for Whitehead, the spatiotemporally extensive morphological structure of actualities and nexus of actualities given via “coordinate division” of actuality, primarily pertinent to the physical pole, is as crucial to concrescence as the intensive features of their relations given via “genetic division” of actualization, primarily pertinent to the mental pole. This close relationship, attended to in detail in chapter 5, is a key aspect of the dipolarity of concrescence in Whiteheadian metaphysics and the avoidance of a Cartesian bifurcated Nature.

It is hoped, then, that the close, concept-by-concept correlation proposed in this book will serve to demonstrate how quantum mechanics, as a fundamental physical exemplification of Whitehead’s metaphysical scheme, might be heuristically useful toward a sound understanding of this scheme, and vice versa. Quantum mechanical concepts presented in Part I will thus be easily recognized when encountered in their analogous Whiteheadian forms in Part II; and likewise, readers already familiar with Whitehead will recognize these forms in their analogous quantum mechanical incarnations in Part I.
Notes


8. Ibid., 196.

9. Ibid., 199.


11. Ibid., 361.


17. Ibid.


20. Ibid., 40.

21. Ibid., 149.

22. Ibid., 149.

23. Ibid., 44.

24. Ibid., 43.

25. Ibid., 164.

37. The most thorough and systematic example of an interpretation of quantum mechanics that explicitly recognizes these desiderata is to be found in Roland Omnès's *The Interpretation of Quantum Mechanics* (Princeton, N.J.: Princeton University Press, 1994); although some readers might find them too technical, his "21 Theses," which pertain to these philosophical desiderata, are extremely useful.


39. Ibid., 278.
