DIVINE ACTION AND QUANTUM THEORY

by Thomas F. Tracy

Abstract. Recent articles by Nicholas Saunders, Carl Helrich, and Jeffrey Koperski raise important questions about attempts to make use of quantum mechanics in giving an account of particular divine action in the world. In response, I make two principal points. First, some of the most pointed theological criticisms lose their force if we attend with sufficient care to the limited aims of proposals about divine action at points of quantum indetermination. Second, given the current state of knowledge, it remains an open option to make theological use of an indeterministic interpretation of quantum mechanics. Any such proposal, however, will be an exploratory hypothesis offered in the face of deep uncertainties regarding the measurement problem and the presence in natural systems of amplifiers for quantum effects.

Keywords: amplification of quantum effects; creation; determinism versus indeterminism; divine action; interpretations of quantum theory; measurement problem; providence.

One of the remarkable characteristics of quantum mechanics has been its tendency to inspire sober-minded physicists to try their hand at *meta*physics. This is in part a result of the notorious difficulty of explaining what the well-established mathematical formalism of quantum mechanics tells us about the world. If we refuse to join Niels Bohr in an essentially instrumentalist account, then we face a bewildering variety of interpretive options that attempt to represent the physical systems whose behavior is captured by quantum theory. These interpretive hypotheses, whether they posit the collapse of the wave function or the proliferation of branching

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universes or the existence of pilot waves, push imagination beyond the bounds of our conventional expectations about the world and stretch our conceptual resources to their limits. John Bell, who did so much to reveal the deeply puzzling character of the quantum realm, published his collected essays under the title *Speakable and Unspeakable in Quantum Mechanics* (1987). This evocative phrase quite naturally suggests a parallel with the classical struggles of theologians to speak of a reality that inevitably exceeds our conceptual grasp.

It is no wonder, then, that theologians want to get into this game. Recent *Zygon* articles (September 2000) by Nicholas Saunders, Carl S. Helrich, and Jeffrey Koperski provide some helpful cautionary remarks about one of the ways in which contemporary theologians have begun to appropriate quantum physics. A number of thinkers, myself included, have speculated about the possible bearing of indeterministic interpretations of quantum mechanics on theological accounts of particular divine action in the world.[1] The essays in *Zygon* advance the discussion of this fascinating (and perilous) topic by identifying some of the principal scientific issues that must be explored in greater detail as we assess the prospects for creative theological responses to quantum physics. In adding my voice to this conversation, I would like to comment briefly on two issues. First, I want to emphasize the particular theological aims of proposals about divine action through quantum indeterminism. Greg Peterson reminds us in this issue that "the theology in this discussion matters as much as the science" (Peterson 2000, 884); I agree and will argue that insufficient attention to the theological context in which these proposals are offered results in criticisms directed at the wrong target. Second, I want to argue that a theological interpretation of quantum theory remains an open option, though any such proposal must be carefully qualified and offered as a tentative theological hypothesis rather than a settled position.

The Theological Context

One of the many virtues of Saunders's essay is that he acknowledges and discusses the theological concerns that motivate proposals about divine action and quantum indeterminism. I think that more consistent attention to this theological context, however, will lead to a different conclusion than the one he reaches. At the end of his essay, Saunders suggests that divine action at points of quantum chance cannot provide an adequately robust account of divine providence. In order to produce even a modest change in the course of events at the macroscopic level, God would have to determine a staggering number of otherwise underdetermined quantum transitions over an enormous period of time. Deflecting the course of an asteroid, for example, would take millions of years (2000, 540). Saunders notes that a possible solution to this problem is to contend that God makes use of structures in nature that amplify quantum effects, so that small num-

bers of events at the microlevel can have significant macroscopic results. But in this case, he argues, God's action is dependent upon the conjunction of indeterministic quantum transitions (measurement events) and natural amplifiers, and this renders God's action episodic and "limited to the potentialities given to him by creation." Saunders concludes that "the resulting view of divine action is far from the biblical and traditional accounts of providence" and is theologically "untenable" (2000, 541–42).

This conclusion would be warranted *if* the only or primary mode of divine action were by resolving quantum indeterminacies. But there are good reasons not to say this, and none of the thinkers who have recently explored the possibilities for this mode of divine action has done so. On the contrary, most affirm that the primary mode of divine action is as the creator of all finite things. Saunders in fact acknowledges this point early in his discussion but then overlooks it in constructing his concluding argument. If we take the doctrine of creation (understood, for the purposes of this discussion, as *creatio ex nihilo,* creation from nothing) as the wider setting within which to develop the idea of divine action through quantum events, then it becomes apparent that the *given* potentialities of nature are given *by* God, not *to* God. God acts most fundamentally by establishing and sustaining the structures of nature, and only secondarily by redirecting events within those structures. This divine creative activity sets the direction of cosmic history and so is the primary mode of God's providential governance of the world. Note that in a deterministic universe, the act of establishing the laws of nature and the initial, or boundary, conditions of the universe would fix the entire course of events; in such a world, every event could be regarded as an indirect act of God brought about through the operation of secondary (i.e., created) causes. If some of the laws of nature are irreducibly probabilistic, then our account of divine action will be more complex, but the fundamental direction of events will nonetheless fall within God's general providence, and much of what happens in cosmic history will be built into God's creative intention for the world.

The idea of divine action through indeterministic transitions in the natural order, therefore, does not carry the whole weight of traditional affirmations about divine providence but rather has a specific and limited role to play within such an account. What exactly is that role? Why would a theologian concerned with divine action not only affirm that God establishes the course of history as its creator but also make the additional claim that God acts at points of causal underdetermination in the structures of nature? Suppose for a moment that the world is a perfectly deterministic causal structure; that is, every event backward and forward in time could in principle (though not in fact, given chaos theory) be deduced from the laws of nature conjoined with a complete description of the state of the universe at any moment. As we just noted, God determines the entire history of such a universe by establishing these laws and setting the initial conditions under which they operate. This certainly provides a powerful

account of God's providential sovereignty. But if this is all we say, then although the whole of history will be God's act, God does not act in history; we might say that God *enacts* history but does not act *within* it to alter the course of events. If we think it theologically important to say the latter as well as the former, then it appears that we must invoke miracles; given the deterministic structure of the world, God's action will interrupt an otherwise closed and complete causal series. Although we should not deny that this is possible for the creator of the natural order, the evidential and theological problems about miracles provide good reasons to deny that this is the customary mode of divine action in history. We are left, therefore, with just two alternatives: either give up the idea of particular divine action in history or bear the various burdens of argument associated with miracles. Is there a way out of this dilemma? Suppose that the structures of nature are not causally closed, but rather include (a) indeterministic transitions that (b) at least sometimes make a difference in the subsequent course of events. In this case, we can conceive of God acting *in* history to bring about particular effects by determining some or all of these otherwise undetermined events, and yet this direct divine action will not displace or disrupt finite causal relationships.

This roughly captures, I think, the reasoning that leads to proposals about God acting through natural indeterminisms, whether quantum mechanical or otherwise. The most compelling theological challenge to such proposals is not that they are unable by themselves to do the whole job in giving an account of divine action but rather that they may be theologically *unnecessary*. It might be argued, for example, that the idea of special, or particular, divine action can be adequately explained without appealing to direct action in the world. Even if God's providential activity is understood entirely as the outworking of the potentialities that God builds into the universe in creation, we can still identify particular events as special divine acts in the sense that (1) these events play a distinctive causal role in advancing God's purposes for the world's history, or (2) these events play a distinctive epistemic role in disclosing God's purposes to us. The principal objection to this interpretation of special divine action is that it fails to allow for divine actions that *respond* to human actions; it appears that God will have to act directly in the course of history in order to interact with free creatures.[2] Here we find the central (though not sole) theological concern that is addressed by the idea of divine action through natural indeterminisms, namely, the concern to provide a means by which God can affect the course of events once history is underway without disrupting the natural causal order. The primary work of divine providence is carried out by creating and sustaining the structures of natural law that set the course of the world's history. Proposals about noninterventionist direct divine action add to this basic account the further (and clearly secondary) idea that God might act at points of underdetermination in nature to turn events in new directions that serve God's particular purposes.

The Scientific Context

Suppose, for the sake of argument, that an adequately rich understanding of God's providential activity must include a place for divine actions that redirect the course of events once the world's history is underway. Can quantum mechanics plausibly be enlisted in the construction of such an account? On this question, Saunders, Helrich, and Koperski all offer important scientific reasons to be doubtful about the prospects for an affirmative reply. I share many of their misgivings and will add some of my own, but I also want to argue that it is too soon to give up on the idea of divine action through quantum indetermination; given the current state of knowledge this remains a more promising possibility than they suggest. There are at least three principal areas of difficulty that such a proposal must face.

1. Multiple Interpretations of Quantum Mechanics. The first and most obvious difficulty is that quantum theory can be interpreted deterministically. It is fair to say that the currently dominant interpretations of quantum mechanics are indeterministic, but the question is by no means settled. According to the prevailing view, some of the properties of a quantum entity (e.g., an electron) can be expressed only as a sum of probabilities (on measurement) for every possible particular state of the entity; this holds, for example, for the electron's position, momentum, and spin orientation (but not for its mass, charge, and magnitude of spin). These indeterminate properties undergo a deterministic evolution according to the Schrödinger wave equation until a measurement is made, at which point a determinate value is obtained for the measured property. On the standard interpretation, this collapse of the wave function cannot be further explained; there are no hidden variables that, if we knew them, would allow us to assign fully determinate properties to the entity at every moment and therefore explain the measured result as having been causally determined by antecedent conditions. It is here that we encounter the indeterministic character of quantum systems; the transition from an indeterminate (but deterministically evolving) superposition of possibilities to a particular determinate state represents a point of ontological chance and causal openness in the structure of the world.[3]

This interpretation of quantum theory has not gone uncontested. Although John Bell established that the theoretical predictions of quantum mechanics are incompatible with local hidden variable theories, David Bohm (1952) was able to develop a nonlocal hidden variable interpretation of quantum theory. On Bohm's account, the probabilistic character of quantum mechanics is strictly an artifact of the limits of our knowledge and does not reflect any indeterminateness in the properties of the quantum entities or any indeterminism in their causal histories. For a variety of reasons, some of which Carl Helrich discusses briefly (2000, 502), Bohm's

view has not been widely embraced. But Bohm is not the only physicist to offer a deterministic interpretation of quantum mechanics. In a rather different way, many-worlds interpretations are deterministic, insofar as they insist that when measurement takes place all the possibilities (of nonzero amplitude) prescribed by the wave equation are actualized (DeWitt and Graham 1973). There is no indeterministic transition from superposed possibilities to a single actuality: the wave equation does not collapse; rather the world branches, and it does so in accordance with the deterministic evolution of the wave function.

This interpretive pluralism creates both an opportunity and a hazard for the theologian. On the one hand, it is perfectly legitimate under these circumstances for a thinker grappling with the theology of nature to prefer one interpretation to another on theological grounds. Indeed, there can be no theological appropriation of quantum mechanics that does not make use of one or another of the currently viable interpretations. On the other hand, if we cast our theological lot with a particular interpretation, we take the risk that new developments in physics or in the philosophy of physics will significantly undercut our theological constructions. It is important to acknowledge this possibility in framing our discussion of these matters, and this suggests two caveats. First, the particular interpretive approach one favors should not be presented as *the* conclusion to be drawn from quantum mechanics. Second, proposals about the theological relevance of quantum theory should be regarded as tentative and provisional hypotheses that reflect the current uncertainty of the relevant science and the extraordinary difficulty of interpreting it. With these provisos in mind, however, theologians are entirely within their rights in making use of an indeterministic interpretation of quantum mechanics.

2. The Measurement Problem. One of the considerations driving the proliferation of interpretations of quantum theory is the nest of puzzles generated by the role of measurement in the standard interpretation. As we noted, a quantum system can be seen as a superimposed mix of alternative possibilities that evolves deterministically in accordance with the wave equation. When a measurement is made on the system, however, it collapses to a single determinate value for the measured property. Here we encounter one of the central puzzles of quantum theory. What is it about the act of measurement that induces the collapse of the wave function? How and where does the indeterminateness of quantum entities give way to the definiteness of macroscopic objects?

The measurement problem appears to generate a particular difficulty for theological appeals to quantum indeterminism. If causal openness is found only in the collapse of the wave function, and if the wave function collapses only when measurement takes place, then God's action would seem to be episodic and dependent on the acts of creatures. Saunders contends that this restricts God's action in a way that severely undercuts

the usefulness of quantum indeterminism for a theology of divine action. There are two things to say in response. First, it is important to note that state reduction takes place throughout the natural world, and not only in the laboratory. "Such events occur *constantly* in the universe whenever elementary particles interact irreversibly with molecules, gases, solids, and plasmas" (Russell 1998, 204). Russell mentions a number of particular examples: Brownian motion, blackbody radiation, the photoelectric effect, fission and fusion, radioactive decay. It is worth noting that recent analyses of the phenomenon of decoherence (i.e., the reduction, on very short time scales, of the pure state of a quantum system to a mixed state when the system interacts with its macroscopic environment) point to the ubiquity of state reduction. But decoherence does not solve the measurement problem, because it does not explain the further reduction to a particular determinate state. Second, and more fundamentally, the measurement problem is a highly unsettled aspect of quantum theory. The very concept of measurement is part of the problem; it is not clear what in the measurement event occasions the collapse of the wave function (e.g., the act of recording the result? the notice taken by a conscious observer?). This difficulty lies at the heart of a broader problem in quantum theory about the relation of the indeterminate microworld to the world of classical objects. Given the deep uncertainty about what measurement is and about when and why it occurs, it is too soon to conclude that this issue poses a special (and fatal) problem for theological interpretations of quantum mechanics.

Saunders notes four ways in which God might act upon a quantum system so as to affect the outcome of measurement. I think that only one of these (that "God controls the outcome of measurement") preserves the lawful relationships that quantum theory describes. This is the only option, therefore, that will be helpful to a theologian who wishes to contend that God acts through quantum indeterminisms without disturbing the causal structures of nature. Saunders notes that this possibility "does not present us with any specific problems," but he suggests that if one says (as does Nancey Murphy [1995]) that God determines *every* measurement event, then "God is simply deceiving us" by letting us think that quantum systems have a probabilistic character (Saunders 2000, 539). He also holds that this view is "scientifically irreconcilable with quantum theory" (p. 541). For these reasons he favors an option that I have discussed, namely, that God acts in only some quantum transitions (Tracy 1995, 320–22). Much as I would welcome the support, it seems to me that this particular objection to Murphy's view is mistaken. Saunders's theological and scientific objections appear to suppose that if God determines every otherwise undetermined quantum transition, then these systems are not in reality probabilistic. The reply to this worry is that the probabilistic relationship holds between prior states of the system and the measured state, and this relationship is preserved whether or not God determines the outcome of some or all quantum transitions.

3. The Amplification of Quantum Effects. Even if indeterministic transitions of the sort associated with measurement are a pervasive feature of the world, they will be largely irrelevant to the theologian's interest in special divine action if they are entirely dampened out by their accumulation in the statistical patterns that generate deterministic regularities at the level of classical objects. Nothing is gained by the claim that God determines some or all of the otherwise undetermined events at the quantum level, unless those events sometimes set in motion particular causal chains with macroscopic consequences.

It is clear that indeterministic transitions in quantum systems *can* have macroscopic effects. On the standard interpretation, precisely this is what happens when physicists make measurements on quantum systems in the lab. The more controversial question is whether nature is arranged in such a way that this amplification of quantum effects can occur apart from human contrivance. This, of course, is a question of empirical fact, and it is an unsettled one. Koperski argues that the idea of chaotic amplification of quantum effects, while elegant and enticing, faces empirical objections. I largely agree with his cautionary analysis, which emphasizes the limits of our current understanding, first, of the role and pervasiveness of chaotic systems in the macroscopic world, and second (and more fundamentally), of how nonlinear chaotic dynamics emerges out of the linear development of quantum systems.

It is important to note, however, that the idea of amplification of quantum effects does not rise or fall solely with the destiny of quantum chaos. As Helrich points out in reply to Koperski, there do appear to be structures in nature that register and then amplify the results of chance events at the quantum level (Helrich 2000, 501). Helrich notes that vision involves a dramatic biochemical augmentation of the interaction between photons and molecular structures in the retina. The nervous system appears to rely extensively on amplification processes of this sort. Further, a number of authors have pointed out that genetic mutation can be induced by a variety of quantum mechanical transitions. In discussing the measurement problem, Alastair Rae offers the following example:

> Mutations can be caused by the passage of high-energy cosmic ray particles. But these cosmic rays are clearly subject to the laws of quantum physics and each cosmic ray particle has a range of possible paths to follow, only some of which give rise to the mutation. The mutation therefore fulfils the role of a measuring event, similar to the photon being detected by the polarizer. (Rae 1986, 61)

Mutation may in effect record the interaction with a quantum mechanical entity, and then the phenotypic expression amplifies this change, exposing it to the selective pressures of evolutionary processes, which may in turn further amplify (or extinguish) it. Robert Russell has offered a careful development of the idea that God might act in evolutionary processes by

affecting quantum transitions that result in mutations in the germ line of an organism (Russell 1998, 205–8). There are a variety of paths, then, by which quantum effects might trigger novel causal chains that have significant macroscopic results. It remains to be seen, however, just how widespread these natural amplifiers actually are. Here again, theological interpretation is contingent upon more fully developed empirical understanding.

Conclusion

Any theological proposal tied to disputed scientific questions must be carefully qualified and put forward with a significant degree of diffidence. Given the current state of knowledge, however, it remains a viable possibility to hold that God might act through indeterministic transitions in quantum systems, and thereby (1) bring about particular effects in the world that were not built into history from the beginning, and (2) do so without *intervening*, if by this we mean interrupting the ordinary lawful operations of the natural order. Clearly, this conception of divine action depends upon a whole series of interpretive judgments and on unsettled questions of fact, and so it has more the character of a program for further research than of a thesis that can be confidently asserted. How seriously we take this possibility will depend not only on scientific developments (e.g., those regarding the measurement problem, the relation of the micro and macro worlds, and the relation of quantum mechanics and chaos) but also on whether we think a proposal that serves this particular purpose is needed as a component in the theology of divine action. The key theological consideration is whether divine action in response to human actions requires that God act in ways that affect the course of events once the world's history is underway. This is an important, but clearly secondary, element in considering God's relation to the world in action; God acts first and foremost as the creator and sustainer of all finite things, with all their intricate lawful order and unfolding potentiality. If we find, however, that our best physical theories invite an ontological interpretation that gives a significant role to indeterministic chance within the structures of nature, then this opens up some intriguing options in constructing an account of God's providential guidance of the world's history.

Notes

1. See Pollard 1958; papers by Ellis, Murphy, and Tracy in Russell, Murphy, and Peacocke 1995; Russell in Russell, Stoeger, and Ayala 1998; Ellis, Russell, and Tracy in Russell, Polkinghorne, Clayton, and Wegter-McNelly in press.
2. This is not the end of the argument. There are conceptual stratagems in philosophical theology that make it possible to think of God responding in the original plan of creation to the choices that God knows will be made by the free agents that God will create. This peculiar knowledge (a knowledge of what merely possible agents will freely choose to do if given the chance) was introduced into sixteenth-century theological disputes by Luis de Molina, and it has contemporary proponents, e.g., Flint 1998.

3. Werner Heisenberg (1958) is well known for this indeterministic interpretation of quantum theory.

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