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Drees, W.B.

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Chaos and Complexity

Scientific Perspectives on Divine Action

Robert John Russell
Nancey Murphy
Arthur R. Peacocke

Editors



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GAPS FOR GOD?

Willem B. Drees

Chaotic and complex processes are as much a part of natural reality as linear and simple processes. Theories of chaotic and complex systems have made clear, even more than before, that a naturalistic explanation may be available even in the absence of predictability. In this sense, they result in a shift in our understanding of 'understanding.' Theories of complex systems have, by the explanations they offer and the shift in the concept of explanation, closed gaps in our understanding of nature. Thereby they have enhanced the strength of a naturalistic view of reality.

The first section will develop this in a discussion of John Polkinghorne's understanding of the unpredictability of natural processes as a locus for divine action in the world. The second section will give a more general discussion of 'explanation' as understood in contemporary philosophy of science. One might discern two conceptions of explanation in contemporary philosophy of science. Ontic views of explanation consider an event explained if it is understood as a possible consequence of a causal mechanism. Epistemic views of explanation consider phenomena and laws explained if they are seen as part of a wider framework. Chaotic processes can be considered explained, or explainable, within each of these conceptions of explanation. Thus, this more general argument supports the conclusion that a quest for gaps in chaotic or complex processes is misguided.

Denying such gaps within natural processes does not foreclose all options for a religious view of reality, as the framework does not explain the framework itself (upon an epistemic view of explanation) and the mechanisms do not explain the mechanisms (upon an ontic view of explanation). Thus, questions about the whole and about the most fundamental structures of reality are not excluded. One way of developing such an argument of a more general nature, focusing on the world as a whole, is Arthur Peacocke's model for particular divine action via "top-down causation." Some weaknesses in this position will be pointed out in the third section. Hence, rather than seek to understand God's action *in* the world, we might attempt to envisage the world *as* God's action. Limit questions about reality are persistent. Discussions about religion in relation to the whole of reality (cosmology) and to the most fundamental structures of reality (e.g., quantum physics), as well as discussions about the nature of scientific and religious knowledge (which, in different ways, seek to acquire a view of the world from a point within the world), are much more credible than a quest for gaps in the chaotic and complex. Even if complex phenomena within reality are understood naturalistically, the world as such is not thereby explained. Hence, there remains room for a sense of wonder and gratitude. The world may still be seen as dependent upon some source which transcends the world.

Before embarking on the critical discussion of the proposals by Polkinghorne (section 1) and Peacocke (section 3), I wish to say that I focus on these authors

because I think their approaches are good examples of their kind and deserve a significant role in subsequent discussions. I will emphasize those aspects where I perceive problems rather than the many aspects which I admire and appreciate.

A second preliminary remark: I will not distinguish in detail between chaotic processes and processes of self-organization, though in the first and second sections the focus will be on limited predictability (which some take as a sign of openness), whereas in the third section the focus will be on the appearance of order (which some take as a sign of a "self," or even of "intentionality").

A third, more fundamental preliminary remark: Arguments are shaped by assumptions and by the audience one has in mind. This essay is primarily written with an audience of people like myself in mind: those who take science seriously and who hold that there is power (for better and for worse) in religious traditions and symbols, but who are not easily persuaded by traditional doctrine. On my view, intellectual investigation in our time has to take the sciences very seriously, and thus has to favor them over other alleged sources of knowledge, whether astrology, common sense folk wisdom, or religious traditions, including the Christian tradition. Otherwise, such investigation runs the risk of demanding "less than it could of theologians and more than it should of scientists."¹ The burden is on theology rather than on science. As Peacocke has put it, the retreat to conservative positions is "a sign not so much of a recovery of faith as of a loss of nerve before the onslaught of new perceptions of the world."² With Gerd Theissen, I am convinced that only by deeply immersing ourselves in science, rather than stopping short of the innermost sanctuaries, the tradition may show up in a new light.³

1 Polkinghorne's Defense of Divine Action in the Openness of Processes

Theories regarding chaotic behavior introduce an openness into our description of the natural world which has been missing from classical Newtonian physics so far.

¹L.B. Eaves, "Adequacy or Orthodoxy? Choosing Sides at the Frontier," *Zygon* 26 (1991): 496. Thus I deviate from William Stoeger (see his article, "Describing God's Action in the World in the Light of Scientific Knowledge of Reality" [in this volume]). At the conference he took the position that we should start from presuppositions which favor neither the sciences nor religion. This seems to me to assume more equality and neutrality than is warranted. Unlike Stoeger, I do not consider as neutral presuppositions the existence of an active God and the reliability of knowledge provided by the sources of religious knowledge, such as scripture, tradition, and experience. In giving primacy to the sciences in intellectual matters, I also deviate from contributions which employ highly theological language.

²Arthur R. Peacocke, *Theology for a Scientific Age: Being and Becoming—Natural and Divine* (Oxford: Basil Blackwell, 1990), ix.

³Gerd Theissen, *Biblical Faith: An Evolutionary Approach* (London: SCM Press, 1984), xi.

This openness would be a kind of "local contingency"⁴ which might allow for human or divine free will and human or divine agency. This view has been eloquently defended by Anglican priest and theoretical physicist John Polkinghorne.

In a bottom-up description of the physical world, the onset of flexible openness is signaled by the myriad possibilities of future development which present themselves to a complex dynamical system. In a quasi-deterministic account they arise from the greatly differing trajectories which would result from initial conditions differing only infinitesimally from one another. Because of their undifferentiable proximity of circumstance, there is no energetic discrimination between these possibilities. The "choice" of the path actually followed corresponds not to the result of some physically causal act (in the sense of an energy input) but rather to a "selection" from options (in the sense of an information input).

It is by no means clear that information input of the kind described originates solely from animals, humankind, and whatever similar agents there might be. I do not believe that God is contained within the mind/matter confines of the world, but it is entirely conceivable that he might interact with it (both in relation to humanity and in relation to all other open process) in the form of information input. . . . God is not pictured as an interfering agent among other agencies. (That would correspond to energy input.) Instead, form is given to the possibility that he influences his creation in a non-energetic way.⁵

The laws of nature allow for gaps where one might envisage divine and/or human action. Central to this argument is the possibility of information input without energy input, thus without interfering with physical laws regarding energy.

I question this line of argument for several reasons, especially insofar as it appeals to chaos theories and the like. Even if there is no difference in energy between two states, energy might still be needed to change the system from one definite state to another. This energy is taken from the background (with its non-zero temperature acting as a source of energy fluctuations), but it is not a choice made by the system itself. Self-organization should perhaps be more properly named "hetero-organization," organization triggered by the immediate environment. In a sense Polkinghorne grants this when he speaks about information input, which sounds like external determination rather than self-organization, though he also uses the argument to argue for human self-determination.

⁴See Robert John Russell, "Contingency in Physics and Cosmology: A Critique of the Theology of Wolfhart Pannenberg," *Zygon* 23, no. 1 (March 1988), for a definition of "local contingency."

⁵John C. Polkinghorne, *Reason and Reality: The Relationship between Science and Theology* (London: SPCK Press, 1991), 45. See also *idem*, "The Laws of Nature and the Laws of Physics" in *Quantum Cosmology and the Laws of Nature: Scientific Perspectives on Divine Action*, ed. Robert John Russell, Nancy Murphy, and C.J. Isham (Vatican City State: Vatican Observatory, 1993; and Berkeley, CA: Center for Theology and the Natural Sciences, 1993), 437-48.

Polkinghorne's argument is based upon the possibility that there is a significant difference in output, even though there is no energy difference in the input. Take, for instance, two different mental acts corresponding to a choice between two options. We experience them as different in information content, not (*qua* mental acts) as physically different in energy or labor involved. However, that may well be an illusion, due to the enormous amplificatory powers of the central nervous system.⁶ Theories on chaos and self-organization show just this, that amplificatory powers of physical systems with respect to small initial differences are much more impressive than was previously thought. One should avoid confusing zero and close to zero in this context; it is essential to Polkinghorne's position that the energy input is absolutely zero rather than almost infinitesimally close to zero, as in the case of low energy events acting as switches modulating processes which expend larger, observable amounts of energy.

In *Science and Providence* Polkinghorne takes the example of a bead at the top of an inverted U-shaped wire. In this case, he argues, there would be no energy barrier between the options of moving the bead to the left or to the right; God could act without input of energy.⁷ An objection to this claim is that if God were to act without input of energy, God's action would have to be infinitely slow. Technically speaking, a basic rule of quantum mechanics is $\Delta E \cdot \Delta t \geq \hbar/2$ (just like the better known uncertainty relation for position and momentum). Hence, if the energy is to become zero, the time will have to extend to infinity. However, infinitely slow action is ruled out, as the decisive input of information should take place before energetic disturbances have changed the situation.⁸

The relation between providing information and spending energy can also be argued more positively. Information which is embodied physically through two (or more) distinct states, representing 0 and 1, requires a minimal energy-difference to write or read. This is a consequence of the second law of thermodynamics. The relevant inequality⁹ is $\Delta I \leq \Delta E/k_B T \ln 2$, which is equivalent to $\Delta E \geq \Delta I \cdot k_B T \ln 2$.

There seems to be no basis in physics for the claim that there is transfer of information without transfer of energy. Invoking quantum physics to provide the missing premise is problematic. Working with a mixture of classical and quantum physics, eclectically invoking the one which fits best at any specific stage of the

⁶Daniel C. Dennett, *Elbow Room: The Varieties of Free Will Worth Wanting* (Cambridge, MA: MIT Press, 1984), 77-78.

⁷Polkinghorne, *Science and Providence: God's Interaction with the World* (Boston: Shambhala, 1989), 32.

⁸George F.R. Ellis suggests in his essay "Ordinary and Extraordinary Divine Action: The Nexus of Intervention," (in this volume) that intervention without energy can take place by controlling the timing of quantum events, say the decay of an excited atom. This seems to violate the same Heisenberg uncertainty relation between energy and time at the other end: controlling the timing precisely would imply a major indeterminacy in energy.

⁹Leon Brillouin, *Science and Information Theory*, 2d. ed. (New York: Academic Press, 1962), 681; see also John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle* (Oxford: Clarendon Press, 1986), 661.

argument, may be acceptable in a pragmatic context; however, it is methodologically unsatisfactorily once one aims at more fundamental, metaphysical claims. Once one understands the world as a quantum world throughout, one has to deal with the question whether there is a similar divergence of trajectories in the quantum world as there is in the classical world of chaos. I am not capable of judging that issue but, as far as I am aware of the technical literature on "quantum chaos," the question has been answered in the negative.

Polkinghorne is cautious about quantum chaos. He offers another argument for ontological openness:

[I]f apparently open behavior is associated with underlying apparently deterministic equations, which is to be taken to have greater ontological seriousness—the behavior or the equations?¹⁰

This preference for the phenomena (unpredictability) rather than the current explanation (*deterministic* chaos) is problematic, at least given Polkinghorne's defense of critical realism. Defenses of critical realism argue from explanatory power to ontology, that is, to the reality of the theoretical entities postulated in the explanation. In this sense, "epistemology models ontology," as Polkinghorne affirms and which he interprets as "acquired knowledge is a guide to the way things are."¹¹ The disagreement is as to what constitutes the "epistemology," or the "acquired knowledge," which the convictions about the underlying entities and processes have to follow. Polkinghorne seems to assume that the "epistemology" which is to be followed is the limited predictability (which he sees as an indication of ontological openness). However, the epistemology is much richer than the observation of limited predictability. The epistemology includes the theory which explains that unpredictability and the processes by means of non-linear, deterministic equations. In that sense, a comparison with the analysis of quantum uncertainty is mistaken, as there the theory allows, at least on some major interpretations, the conclusion of "genuine indeterminacy."¹² Polkinghorne prefers to interpret unpredictability as a sign of ontological openness, bypassing the (deterministic) explanatory theory available. Sticking to the phenomena and discarding the available explanation is not a critical realist strategy, but an empiricist one.

The move from a deterministic theory to ontological openness is also problematic in relation to the science at hand: there is no new principle involved in chaotic systems. There are, of course, new discoveries of order in and through chaos. And the iteration characteristic of self-organizing systems—that the outcome of one stage, say a living organism, is itself the starting point of the next stage—enriches our understanding of the historicity of nature.¹³ Still, the scientific

¹⁰Polkinghorne, *Reason and Reality*, 41.

¹¹Polkinghorne, "Laws of Nature," 440.

¹²Polkinghorne, *Reason and Reality*, 42; and *idem*, "Laws of Nature," 440.

¹³See Bernd-Olaf Küppers, "Understanding Complexity" (in this volume); and *idem*, "On a Fundamental Paradigm Shift in the Natural Sciences," in *Selforganization: Portrait of a Scientific Revolution*, ed. Wolfgang Krohn, Gunter Kuppes, and Helga Nowotny

study of self-organizing, complex, and chaotic systems has not revealed new gaps to be filled by some external actor. Although complex systems exhibit behavior as if they were guided by an external organizing principle or an intentional self, the theories show that such behavior is explainable without invoking any such actor—whether a self, a life force, or a divine Informator. As such, chaos theory is the extension of the bottom-up program to complex systems rather than a suggestion of the existence of some “top” from which “intentional causation” as “information” proceeds downwards.

Polkinghorne acknowledges that the use of openness as the causal joint between God and the world seems like a “God-of-the-gaps” strategy, even though God is not competing as “an alternative source of energetic causation.” However, Polkinghorne argues that there is a fundamental difference between these gaps and earlier gaps, which “were epistemic, and thus extrinsic to nature, mere patches of current scientific ignorance.”¹ I do agree that there is a fundamental difference, but it works in the other direction. Whereas in the case of epistemic gaps reflecting ignorance one might maintain an agnostic stance with respect to the possibility of a regular scientific explanation, with the advent of chaos theories there is no reason for such an open attitude. Though there is unpredictability, there is also an underlying theory. To claim gaps is not merely to remain agnostic where we do not know, but to go against what is currently taken as knowledge—the unpredictability of systems which are described by deterministic equations. At this level, we are not confronted with any indications of “gaps” in the processes, unlike the situation at the quantum level and at the cosmological level.

The newly won scientific insights regarding complexity change our view of the world. Unpredictability is, of course, very relevant beyond the strictly scientific context, especially in the context of ethics. To what extent are we responsible if we have only a limited view of the consequences of our actions? For instance, limited predictability and the instability of systems is very relevant in assessing the risks of a *Jurassic Park*. But it does not offer or undergird a specific view of divine action in individual events or of a causal joint between God and the world. Unpredictability is metaphysically uninteresting, at most a necessary but insufficient condition for metaphysical openness. Peacocke’s alternative intends to avoid the interventionistic approach of seeking gaps as specific causal joints. He envisages God’s interaction with the world as a whole. It is to such ideas that we will turn below. But before turning to alternatives, I would like to consider briefly the concept of scientific explanation in relation to arguments about gaps, as it allows for an additional argument against the attempt considered here to find gaps for divine action within unpredictable and “self-organizing” processes.

(Boston: Kluwer, 1990), 51-63.

¹Polkinghorne, “Laws of Nature,” 446.

2 Explanations and Gaps

If there is in reality an openness which allows for divine action (see Polkinghorne's position in the preceding section), there should be elements in the processes which are not explained sufficiently otherwise. Thus, it seems relevant to spend some time on the notion of *explanation* as it functions in the context of the sciences.

Explanation is one of several notoriously difficult concepts.² The "classic" view is the *covering-law model* of explanation, which explains an event on the basis of one or more general laws and one or more conditions.³ On this view, an explanation is similar in structure to a prediction from initial conditions and a law. The covering-law model is of limited value, as the notion of laws is more adequate to the physical sciences than to the other natural sciences. Besides, the connection between explanation and causation is absent in many cases. For instance, the height of a flagpole is calculated on the basis of the laws of optics, the position of the Sun and the length of the shadow—but it is not caused by these.

Given the problems with the covering-law model, contemporary philosophers have offered other views of explanation. They seek to give accounts of explanation which incorporate not only predictive power but also some other features which make for successful explanations and justify the move from explanatory power to approximate truth. There seem to be two kinds of conceptions of explanation, an epistemic one and an ontic one. For instance, Philip Kitcher stresses unifying power⁴ while Richard Boyd emphasizes a realist view of causes. Kitcher's epistemic approach sets the phenomena in a wider theoretical framework. Boyd seeks an ontic approach, a quest for the causes or mechanisms involved. Such ontic and epistemic approaches "are not mutually exclusive, but, rather, complementary."⁵

²See Philip Gasper, "Causation and Explanation," in *The Philosophy of Science*, ed. Richard Boyd, Philip Gasper, and J.D. Trout (Cambridge, MA: MIT Press, 1991), 289-98; and Philip Kitcher and Wesley C. Salmon, eds., *Scientific Explanation* (Minneapolis, MN: University of Minnesota Press, 1989), of which one essay has been republished independently as Salmon, *Four Decades of Scientific Explanation* (Minneapolis, MN: University of Minnesota Press, 1989).

³C. Hempel and P. Oppenheim, "Studies in the Logic of Explanation," *Philosophy of Science* 15 (1948): 135-75.

⁴Kitcher, "Explanatory Unification," *Philosophy of Science* 48 (1981): 507-31; reprinted in *The Philosophy of Science*, ed. Boyd, et al.

⁵Boyd, "Observations, Explanatory Power, and Simplicity: Toward a Non-Humean Account," in *Observation, Experiment, and Hypothesis in Modern Physical Science*, ed. Peter Achinstein and Owen Hannaway (Cambridge, MA: MIT Press, 1985); reprinted in *Philosophy of Science*, ed. Boyd, et al. For other views of explanation besides the epistemic and ontic views considered here see Bas C. van Fraassen's "pragmatic view" (*The Scientific Image* [Oxford: Clarendon Press, 1980], 97-157); and Salmon's "modal" conception of explanation (*Four Decades*).

⁶Salmon, *Four Decades*, x.

With the distinction between epistemic and ontic views of explanation, we can now return to our reflections on chaotic processes. These processes existed, of course, before they were labeled as such. However, with the discovery by E. Lorenz of a simple set of three equations which showed erratic behavior in 1963, we enter the era of chaos theory. This theory deals with deterministic equations governing processes which are extremely sensitive to minute differences in initial conditions, and which therefore allow only limited predictability.

On an epistemic view of explanation, chaotic processes are explained since they fit into a wider theoretical framework, parts of which have been around for centuries (e.g., differential equations), other elements of which were developed more or less around the same time as chaotic processes were recognized (e.g., fractals). Chaos theory has not diminished the unity of explanatory accounts, but rather has increased it as more phenomena are now treated within the framework of mathematical physics.

An ontic view of explanation is not so much oriented to the structure of our knowledge as to the availability of a mechanism which would explain the phenomena under consideration. With respect to chaotic processes of limited predictability, such a causal account is readily available. Even though we could not have predicted a specific storm two weeks in advance, since we were unable to observe in sufficient detail all the conditions at that moment (e.g., the butterfly effect), we have no problem envisaging a possible causal mechanism which resulted in that storm. We cannot predict the numbers that will come up when we throw a pair of dice. We are unable to predict which way the bead will fall along an inverse U-shaped wire. But in either case, we can envisage how it may have come about the way it actually came about (e.g., due to minute influences from the air, the surface, etc.). Predictability is not a necessary condition for explainability.

We prefer deductive explanations, which tell us that given the conditions and the laws (or the mechanism, or the framework, or whatever understanding of explanation is involved), the event was certain to happen. However, we also have situations where we can say that given the conditions and the laws, it was likely (say with 0.95 probability) or less likely (say with 0.3 probability) to happen. If a theory predicts that an event might happen, say with a probability of 0.3, and it happens, would one say that the theory has explained the event? It certainly explains the possibility of the event, even though it does not explain its occurrence on this occasion. This is the situation which we face, for different reasons, in the case of chaotic processes such as the weather, and in the context of quantum theories. For the moment, I will restrict the discussion to chaotic processes. There the problem is not so much due to an intrinsic openness in reality as described by the laws (as might be the case in quantum physics) but to our limited knowledge of the actual situation.

With respect to a probabilistic explanation necessitated by such insufficient knowledge of the conditions I agree with the following summary of an argument by Richard Jeffrey:

[W]hen a stochastic mechanism—e.g., the tossing of coins or genetic determination of inherited characteristics—produces a variety of outcomes, some more probable and others less probable, we understand those with small probabilities exactly as well as we do those that are highly probable.

Our understanding results from an understanding of that mechanism and the fact that it is stochastic.⁷

Jeffrey's position is expressed within the context of an ontic view of explanation. On this view, we may well have unpredictability without inexplicability, and without an opportunity to postulate openness in the processes involved.

There is a wide range between the explained and an inexplicable event which would be linked with a genuine "gap" in nature, or in our understanding of nature. In between are phenomena which could be explainable but are currently inexplicable as we do not have the correct theory yet—such was the situation with the discovery of "high temperature" superconductivity in ceramic materials. Even without an explanation we assume the phenomenon to be explainable in terms of physics, probably known physics, but otherwise with a modification of known physics. There may also be phenomena which are explainable but will never be predictable—as is the case with chaotic processes. As the events will never be fully predictable, one can never exclude particular divine action hidden in the unpredictability. However, as I see it, if there is no indication of or need for such an assumption of openness and divine action, the assumption is not justified. Quantum uncertainty, such as in the decay of a nucleus, may be of a different kind. Here we have good grounds to exclude an ordinary cause or "hidden variable," and thus an explanation of the limited predictability as a consequences of an unobserved but real physical process. However, even with quantum physics we need to be cautious, as quantum physics will be modified or replaced, and is open to various interpretations.

So far, we have not made an explicit distinction between explanations of particular facts or events and the explanation of laws. However, this distinction is relevant in this context. Most accounts of explanation, including the traditional covering-law model, are primarily concerned with the explanation of facts, assuming a framework (laws, mechanisms, or the like). To some extent, the framework assumed can be considered as a fact to be explained in a wider framework—as Ohm's law for electrical currents can be explained in the context of a more general theory of electromagnetism in combination with some solid state physics. There are sequences of explanations. Chemists refer to astrophysicists for the explanation of the existence of elements and to quantum physicists for the explanation of the bonds between atoms. Somehow, these sequences converge: various questions about the structure of reality are passed on until they end up on the desk of fundamental physicists (dealing with quantum field theory, superstrings, etc.) and questions about the history of reality end up on the desk of the cosmologist. As an American president is said to have had written on a sign on his desk: "The buck stops here." Thus, the physicist and the cosmologist may well say

⁷Salmon, *Four Decades*, 62, referring to R.C. Jeffrey, "Statistical Explanation vs. Statistical Inference," in *Essays in Honor of Carl G. Hempel*, ed. Nicholas Rescher (Dordrecht: Reidel, 1970).

"Only God knows."⁸ This particular position of physicists and cosmologists in the quest for explanation may make it clearer why they get drawn easily into philosophical and theological disputes in a way foreign to geologists, biologists, or chemists. It is not the claim that it is an effective, fruitful, or feasible heuristic strategy to explain all phenomena from "first principles"; calculations and derivations may be beyond our capacities. The argument is that there are limit questions concerning the scientific enterprise. These limit questions show up most clearly in physics and cosmology, and—I would like to add to the example from Misner and Weinberg—in philosophy of science, since on the desk of the philosopher of science rest questions about the nature of the explanations and arguments offered, and the role of human subjects therein.⁹

The position that all phenomena can be explained in a framework which would be "incomplete" only with respect to questions about the basic structure and the whole, is naturalistic. It is well captured in a phrase from the philosophy of John Dewey: "Mountain peaks do not flow unsupported; they do not even rest upon the earth. They are the earth in one of its manifest operations."¹⁰ Such a naturalistic view of reality fits well with contemporary science and contemporary philosophical reflections on the concept of explanation. It is at odds with the quest for an openness for divine action in complex or chaotic processes. However, such a naturalistic view does not exclude theological options at other levels. There still may be speculative theological answers to questions about the framework, the laws and initial conditions, or whatever is assumed.

Quantum physics is one of the options; this is emphasized by George Ellis, Nancey Murphy, and Thomas Tracy in this volume. I do agree that this is a more appropriate level for envisaging divine action than any process at a higher level of reality. However, I am nonetheless skeptical about the use of quantum physics to envisage divine action. One reason is that quantum indeterminacy might be resolved either via a modification of quantum physics or via a different interpreta-

⁸The image of handing questions from one desk to another is taken from C.W. Misner, "Cosmology and Theology," in *Cosmology, History, and Theology*, ed. Wolfgang Yourgrau and Allen D. Breck (New York: Plenum, 1977). See also Steven Weinberg, *Dreams of a Final Theory* (New York: Pantheon Books, 1992), 242. It may be that the distinction between structural and historical questions breaks down in quantum cosmology, but that makes no difference for the argument. On quantum cosmology see C.J. Isham, "Quantum Theories of the Creation of the Universe," in *Quantum Cosmology*.

⁹I only realized after completing this paper that this argument about cosmology, physics, and philosophy of science is parallel to the conclusion I reached in an earlier contribution on time in cosmology, where I argued for two options, a Platonic cosmological one and a constructivist one. See Willem B. Drees, "A Case Against Temporal Critical Realism? Consequences of Quantum Cosmology for Theology," in *Quantum Cosmology*.

¹⁰John Dewey, *Art as Experience* (New York: Minton, Balch & Co., 1934); also quoted by H. Fink in *Free Will and Determinism: Papers from an Interdisciplinary Research Conference, 1986*, ed. Veggo Mortensen and Robert C. Sørensen (Aarhus, Denmark: Aarhus University Press, 1987), 51.

tion. Another reason is that indeterminacy may be an opportunity for a metaphysical supplement to physical causes, but, in my opinion, it does not require such a move. There is no need to adhere to a metaphysical principle of sufficient reason, even though the principle of sufficient reason is a good heuristic notion within any naturalistic approach. I will leave off with these brief remarks, as quantum physics will be the topic of a future conference. The next section will consider an attempt to articulate a notion of divine action at the level of the world as a whole, drawing on our understanding of processes of self-organization in macroscopic systems.

3 Top-Down Causation as Divine Causation

An alternative to an interventionistic view of God's action within processes in the world has been presented by Arthur Peacocke in his *Theology for a Scientific Age*. It relies on the notion of top-down causation. I will briefly present the idea of top-down causation and its application in the context of theology, before making some critical comments.

3.1 Some Examples of Top-Down Causation

There are physical and chemical systems in which we find coordinated behavior of billions of individual molecules. Chemical clocks and the Bénard reaction are examples of this. The system exhibits a global pattern as long as certain conditions at the spatial boundary are maintained. Individual molecules behave according to this global pattern, rather than in the manifold of possible ways described in the statistics of an ideal gas. As Peacocke formulates it, after describing spatial or temporal (rhythmic) patterns:

In both these instances, the changes at the micro-level, that of the constituent units, are what they are because of their incorporation into the system as a whole, which is exerting specific constraints on its units, making them behave otherwise than they would do in isolation.¹¹

Bernd-Olaf Küppers has on various occasions presented theories of self-organizing systems as theories regarding "boundary conditions."¹² There are spatial boundary conditions, such as the two plates which set the non-equilibrium which gives rise to Bénard convection. More relevant to our understanding of reality are DNA molecules, which shape the development of each organism and may be seen as a kind of initial condition. Boundary conditions are, of course, a traditional feature in physical descriptions—corresponding to the freedom of the experimenter to choose a certain experimental set-up. However, in the case of the DNA of organisms, we do not deal with such almost totally contingent boundary conditions. The boundary conditions which are initial to one stage are the outcome

¹¹Peacocke, *Theology*, 53-54.

¹²See Küppers, "Paradigm Shift."

of the preceding step, and so on. They are thus the product of a long iterated sequence that gave rise to organisms with biological complexity.

The relation between mental phenomena and brains is sometimes referred to as another example of top-down causation. According to Peacocke, top-down causation would provide a middle ground between an unacceptable Cartesian dualism of two entities and a physicalist reductionism of mental states to brain states. As far as I understand the discussion, the notion of top-down causation is invoked in an attempt to clarify and illuminate the relation between mind and brain, rather than our understanding of the brain and mind being invoked in order to explain top-down causation. That is the major reason for caution in appealing to this example. Another reason may be that a reductionistic approach, if it includes the environment-organism interaction and the difference between a first-person and a third-person account, has a stronger case than is granted by authors who see the need for top-down causality to explain the mind/brain problem.¹³ However, that would lead us into a discussion which far exceeds the scope of the present paper.

3.2 Top-Down Causation as a Model for the God-World Interaction

Peacocke exercises welcome caution in pointing to the inadequacy of all human models and metaphors regarding God.¹⁴ That, however, does not keep him from an attempt to think through the model of top-down causation.

In the light of these features of the natural world, might we not properly regard the world-as-a-whole as a total system so that its general state can be a "top-down" causative factor in, or constraint upon, what goes on at the myriad levels that comprise it?¹⁵

On this view, divine action could make a difference without violating in any way the regularities and laws. Besides, the model also envisages how natural events, including human decisions and actions such as prayer, could contribute to the state of the whole. This truly would be a model of dialogue between humans and the divine. There is a further gain in this model:

For these ideas of 'top-down' causation by God cannot be expounded without relating them to the concept of God as, in some sense, an agent, least misleadingly described as personal. . . .

My suggestion is that a combination of the notion of top-down causation from the integrated unitive mind/brain state to human bodily action . . . with the recognition of the unity of the human mind/brain/body event . . . together provide a fruitful clue or model for illuminating how we might think of God's interaction with the world. . . . In this model, God

¹³Accounts of the brain and mind without an appeal to "top-down" causation are given by Dennett, *Consciousness Explained* (Boston: Little, Brown & Co., 1991); and John R. Searle, *The Rediscovery of the Mind* (Cambridge, MA: MIT Press, 1992). See also *Scientific American* (September 1992), which is dedicated to the mind/brain question.

¹⁴See Peacocke, *Theology*, 90, 167 and 188.

¹⁵*Ibid.*, 158 and 159.

would be regarded as exerting continuously top-down causative influences on the world-as-a-whole in a way analogous to that whereby we in our thinking can exert effects on our bodies in a 'top-down' manner.¹⁶

This is better conceived of in terms of transfer of information than of energy. The result is more than a general influence on the world: "Initiating divine action on the state of the world-as-a-whole can on this top-down causative model thereby influence particular events in the world," without ever being observed as a divine "intervention."¹⁷

Peacocke acknowledges the problem that a transfer of information requires a transfer of energy at the levels with which we are familiar. However, he locates it at a peculiar place, at the interface between the world-as-a-whole and God, rather than within the natural order. "This seems to me to be the ultimate level of the 'causal joint' conundrum, for it involves the very nature of the divine being in relation to that of matter/energy and seems to me to be the right place to locate the problem."¹⁸

3.3 *God as the Top in Top-Down Causation?*

The issue of energy and information has already been considered above. Here, I will consider the application of the notion of top-down causation to the world-as-a-whole.

The example of the Bénard cell is a clear instance where the conditions at the boundary determine the behavior of billions of individual molecules. However, this is also an example where one could replace the term "top-down causation" by "environment-system interaction." That environment which sets the temperature at the boundary plates is a physical system, just as is the system in which the Bénard cells occur. There is nothing peculiarly global about the experiment; all influences can be traced to local phenomena within the space-time framework. For instance, setting the boundary conditions has no immediate impact on the behavior of molecules at some distance from the boundary; it takes some time to settle into the coordinated state. In the case of DNA the relations are also traceable as local relations within the spacetime framework. The DNA shapes the development of an organism. The environment has an impact on the survival of the organism, the mutations in its DNA, the shuffle of DNA in sexual reproduction, and so on.

In both instances, there is some sense in which a whole (such as the state at the boundary-plates, or the DNA) serves as the boundary for the system, while the next stage of the whole (for instance the DNA of the next generation) is shaped by the development of the system (the organism) in its environment. However, there

¹⁶Ibid., 161.

¹⁷Ibid., 163.

¹⁸Ibid., 164.

is no sense in which the system-as-a-whole has any mysterious causal influence. All causal influences can be traced to local physical influences within the system or between the system and its immediate environment. Boundaries are local phenomena, rather than global states of the system-as-a-whole.

In taking top-down causation as the point of departure for describing the relation between God and particular events, there is a significant extrapolation from particular environments to the encompassing notion of "the world-as-a-whole." God is introduced as the one who sets the boundary conditions for the world-as-a-whole at the global level. This seems to me to be problematic, if not to say unwarranted, with respect to the sciences at hand. In the examples which led to the notion of top-down causation, there is always an important role for the physical environment. One could say that in the example of the Bénard cells it is the environment which acts as the "top," setting the temperature at the plates and thereby the state of the system. And in the DNA example, it is the preceding history which has resulted in the DNA that serves as the boundary condition for the organism that is to develop. When we start talking about "the world-as-a-whole" then the notion of a global context, of an environment, becomes a metaphor. In science, we always deal with a context which is also captured in terms of the same laws of physics. This is, it seems to me, an instance of the distinction between relative information, as it arises in the scientific context, and absolute notions with roots in an idealist philosophy and which keep cropping up in theological use of the science at hand.¹⁹

The problem is not only the presence of absolute notions, but the idea that in the natural realm there can be activity proceeding from such absolutes. With Peacocke I agree that this may be a more appropriate location for "the causal nexus" than any place within the world of natural processes. However, as a quest for an understanding of a causal nexus between the divine and the world it still interferes with any (assumed) completeness of the natural account. A promising alternative which avoids such interference is the reflection upon the natural account itself, and especially the themes of the existence, order, and intelligibility of the world.²⁰ Rather than seeking an understanding of divine action in the world, the world itself is understood as God's action. Whatever strength scientific explanations have, there always remain limit questions about reality and about understand-

¹⁹I owe this distinction to Küppers, during a preparatory meeting in Castel Gandolfo in December 1992. The same problematic move from a relative to an absolute lies behind the distinction between "the future as present," as belonging to the realm of physics, and "the future as future," as the domain of theology, a move which is important for some German and Swiss Protestant authors on theology and science. See A.M. Klaus Müller, *Die präparierte Zeit* (Stuttgart, Germany: Radius Verlag, 1972); and C. Link, *Schöpfung: Schöpfungstheologie angesichts der Herausforderungen des 20. Jahrhunderts*, Handbuch systematischer Theologie, Bd. 7/2 (Gütersloh: Gerd Mohn, 1991), 444.

²⁰See Michael Heller, "Chaos, Probability, and the Comprehensibility of the World" (in this volume).

ing. These may evoke an attitude of wonder and gratitude. Even when phenomena within the world are understandable in a naturalistic way, the world as thus understood may be interpreted from a religious perspective as dependent upon, or created by, a transcendent source.²¹

²¹This will be developed further in W.B. Drees, *Mountain Peaks Do Not Flow Unsupported: A Naturalist View of Religion and a Religious View of Naturalism* (forthcoming, working title). One of the elements in the articulation of a combination of a naturalist view of religion and a religious view of naturalism is the need to differentiate between scientific realism and theological realism; neither does the one build upon the other in the way models in the sciences build upon each other, nor is theological realism defensible along the same lines as defenses of scientific realism.