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CREATION AND SCIENCE

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During the past decade the Vatican Observatory and the Center for Theology and the Natural Sciences in Berkeley, California, have been sponsoring a series of conferences on what they call "scientific perspectives on divine action," which have resulted in the publication of four impressive volumes.[1] What has emerged as a major theme in the contributions of many of the scholars in these volumes is how contemporary science points to a kind of metaphysical space which can allow for divine agency in the world.[2] Thus, for example, the fascination with quantum mechanics and chaos theory, since each has been viewed as providing the metaphysical indeterminacy needed to provide an arena in which God can act.

For many theologians, the value of developments in contemporary science concerns what they perceive to be a fundamental difference from the view of the universe as a causally closed system operating according to the prescriptions of Newtonian mechanics. So long as the universe was seen in Newtonian terms, it was easy, so such an interpretation suggests, to limit divine action to an initial act of creation. Even the notion of God's continual causing of the existence of things was thought to be challenged by the principle of inertia, which seemed to entail the view that the universe was self-sufficient and thus required no appeal outside of itself, once it existed, to account for all motion and change.[3] According to these theologians, the deterministic view of the universe, made famous by Pierre Laplace, has

[1] *Quantum Cosmology and the Laws of Nature* (1993); *Chaos and Complexity* (1995); *Evolutionary and Molecular Biology* (1998); and *Neurosciences and the Person* (1999)

[2] This is a correlative to the need for a similar metaphysical space which allows for the causal agency of creatures.

[3] This view has been set forth by Hans Blumenberg, *The Legitimacy of the Modern Age*, translated by Robert Wallace (Cambridge, MA: MIT Press, 1971) and Wolfhart

been overturned by quantum indeterminism, and, as a result, God could be thought of as acting at the quantum level. Recently some theologians have argued that quantum mechanics allows us to think of divine action as the "providential determination of otherwise undetermined events." God's "governance at the quantum level consists in activating or actualizing one or another of the quantum entity's innate powers at particular instants." In an essay which applies such views to the field of genetics, Robert J. Russell adopts "the *theological* view that God's special action can be considered as objective and non-interventionist if the quantum events underlying genetic mutations are given an indeterminist interpretation philosophically. If it can be shown scientifically that quantum mechanics plays a role in genetic mutations, then by extension it can be claimed theologically that God's action in genetic mutations is a form of objectively special, non-interventionist divine action. Moreover, since genetics plays a key role in biological evolution, we can argue by inference that God's action plays a key role in biological evolution..."[4]

The British physicist and theologian, John Polkinghorne, although critical of the appeal to quantum indeterminacy as a way to make room for divine action in the world, does think that contemporary chaos theory offers a fruitful avenue for theological reflection. "The most obvious thing to say about chaotic systems is that they are intrinsically unpredictable. Their exquisite sensitivity means that we can never know enough to be able to predict with any long-term reliability how they will behave." Polkinghorne argues that the epistemological limitations which chaos theory presents point to a fundamental feature of the world, what he calls an "ontological openness."[5]

Pannenberg, *Toward a Theology of Nature*, translated by Ted Peters (Louisville, KY: Westminster/John Know Press, 1993) and in *Metaphysics and the Idea of God*, translated by Philip Clayton (Grand Rapids, MI: W. B. Eerdmans, 1990). For a discussion of these claims – especially how to understand the principle of inertia – see William E. Carroll, "The Scientific Revolution and Contemporary Discourse on Faith and Reason," in *Faith and Reason*, edited by Timothy Smith (St. Augustine's Press), forthcoming.

[4] Russell, thus, presents a sophisticated form of theistic evolution. Robert J. Russell, "Special Providence and Genetic Mutation: A New Defense of Theistic Evolution," in *Evolutionary and Molecular Biology: Scientific Perspectives on Divine Action*, edited by Robert J. Russell, William R. Stoeger, and Francisco J. Ayala, pp. 191-223, at p. 213 and p. 206, italics in original (Vatican City: Vatican Observatory Publications, 1998). Russell provides an excellent summary of the views of two theologians, Nancey Murphy and Thomas Tracy, on the general theological significance of quantum indeterminismon. p. 214.

[5] "I want to say that the physical world is open in its process, that the future is not just a tautologous spelling-out of what was already implicit in the past, but there is gen-

For Polkinghorne, chaos theory presents us with the possibility of "a metaphysically attractive option of openness, a causal grid from below which delineates an envelope of possibility...within which there remains room for manoeuvre."[6] This "room for manoeuvre," can be seen, according to Polkinghorne, in the act of creation itself, understood as: "...a kenosis (emptying) of divine omnipotence, which allows for something other than God to exist..."[7] Recently, Polkinghorne has written: "The act of creation involves a voluntary limitation, not only of divine power in allowing the other to be, but also of divine knowledge in allowing the future to be open... An evolutionary universe is to be understood theologically as one that is allowed by God, within certain limits, to make itself by exploring and realizing its own inherent fruitfulness. The gift of creaturely freedom is costly, for it carries with it the precariousness inherent in the self-restriction of divine control."[8]

uine novelty, genuine becoming, in the history of the universe... The dead hand of the Laplacean Calculator is relaxed and there is scope for forms of causality other than the energetic transactions of current physical theory. As we shall see there is room for the operation of holistic organizing principles (presently unknown to us, but in principle open to scientific discernment), for human intentionality, and for divine providential interaction." J. Polkinghorne, "The Laws of Nature and the Laws of Physics," in *Quantum Cosmology and the Laws of Nature*, edited by Robert J. Russell, Nancey Murphy, and C.J. Isham (Vatican City: Vatican Observatory Publications, 1993), pp. 441-2.

[6] "How that manoeuvre is executed will depend upon other organizing principles, active in the situation, viewed holistically. A chaotic system faces a future of labyrinthine possibilities, which it will thread its way through according to the indiscernible effects of infinitesimal triggers, nudging it this way or that...[C]haos theory [is] actually an approximation to a more supple reality, these triggers of vanishingly small energy input become non-energetic items of information input ("this way", "that way") as proliferating possibilities are negotiated. The way the envelope of possibility is actually traversed will depend upon *downward causation* by such information input, for whose operation it affords the necessary room for manoeuvre." *Ibid.*, p. 443.

[7] "I am suggesting that we need to go further and recognize that the act of creating the other in its freedom involves also a kenosis of the divine omniscience. God continues to know all that can be known, possessing what philosophers call a current omniscience, but God does not possess an absolute omniscience, for God allows the future to be truly open. I do not think that this negates the Christian hope of ultimate eschatological fulfillment. God may be held to bring about such determinate purpose even if it is by way of contingent paths." *ibid*., pp. 447-8. On this final point see D. Bartholomew, *God of Chance* (London: SCM Press, 1984).

[8] John Polkinghorne, "Chaos Theory and Divine Action," in *Religion and Science*, edited by W. Mark Richardson and Wesley J. Wildman (New York: Routledge, 1996), pp. 250 and 249.

I think that Polkinghorne moves far too easily from claims in epistemology to claims in metaphysics. Various attempts by Polkinghorne, Arthur Peacocke, Nancey Murphy, George Ellis,[9] and others to locate a venue for divine agency in the indeterminism of contemporary physics really amount to the contention that any account of the physical world in the natural sciences is somehow inherently incomplete. In other words, these authors must maintain that the natural sciences cannot in principle provide a complete, coherent scientific account of physical reality.[10]

I do not want to address the complex questions of how properly to interpret quantum mechanics or chaos theory.[11] What I should like to focus on

[9] See their essays in *Chaos and Complexity*, edited by Robert J. Russell, Nancey Murphy, and Arthur Peacocke (Vatican City: Vatican Observatory Publications, 1995).

[10] This is a criticism aptly made by Willem B. Drees in "Gaps for God?" in *Chaos and Complexity, op. cit.*, pp. 223-237. That Polkinghorne is particularly susceptible to this criticism can be seen in the following observation he makes in this same volume: "For a chaotic system, its strange attractor represents the envelope of possibility within which its future motion will be contained. The infinitely variable paths of exploration of this strange attractor are not discriminated from each other by differences of energy. They represent different patterns of behavior, different unfoldings of temporal development. In a conventional interpretation of classical chaos theory, these different patterns of possibility are brought about by sensitive responses to infinitesimal disturbances of the system. Our metaphysical proposal replaces these physical nudges by a causal agency operating in the openness represented by the range of possible behaviors contained within the monoenergetic strange attractor. What was previously seen as the limit of predictability now represents a 'gap' within which other forms of causality can be at work." Polkinghorne, "The Metaphysics of Divine Action," in *Chaos and Complexity...*, pp. 153-4.

[11] The philosophical issues connected to a proper interpretation of quantum mechanics and chaos theory are extraordinarily complex. Robert J. Russell and Wesley J. Wildman ["Chaos: A Mathematical Introduction with Philosophical Reflections," in *Chaos and Complexity..., op. cit.*, pp. 49-90], for example, have argued persuasively that it is philosophically dangerous to move from the essentially mathematical realm of chaos theory to reach conclusions about metaphysical determinism or indeterminism; nor ought one to equate unpredictability with indeterminism. They note the use made by chaos theory in some theological circles: "The development of chaos theory has been welcomed by some theologians as powerful evidence that the universe is metaphysically open (i.e., not completely deterministic) at the macro-level. Metaphysical indeterminacy at the quantum level does not even need to be assumed, on this view, for chaos theory makes room for human freedom and divine acts in history that work wholly within nature's metaphysical openness and do not violate natural laws...[Such an interpretation is] without justification...since it makes little sense to appeal to chaos theory as positive evidence for metaphysical indeterminism when chaos theory is itself so useful for strengthening the hypothesis of metaphysical determinism: it provides a powerful way for determinists to argue that many kinds of apparent randomness in nature should be subsumed under deterministic covering laws." *Ibid.*, pp. 84 and 86.

is the concern for metaphysical space which informs the arguments of so many contemporary writers on science and theology, and to show how a return to Thomas Aquinas' discussion of creation[12] is particularly fruitful, especially his understanding of how God is the complete cause of the whole reality of whatever is and yet in the created world there is a rich array of real secondary causes.[13] God's creative act, for Aquinas, is not an example of divine withdrawal[14] but is, rather, the exercise of divine omnipotence. Furthermore, Aquinas' understanding of creation affirms the integrity and relative autonomy of the physical world and the adequacy of the natural sciences themselves to describe this world. In the thirteenth century, as a result of the translations into Latin of the works of Aristotle and his Muslim commentators, scholars of the caliber of Albert the Great and Thomas Aquinas wrestled with the implications for Christian theology of the most advanced science of their day. Following in the tradition of Muslim and Jewish thinkers, Thomas Aquinas developed an analysis of the doctrine of creation from nothing which remains one of the enduring accomplishments of Western culture. An examination of what he says about creation provides a refreshing clarity for discussions in our own day of the relationship between science and religion.[15]

It seemed to many of Aquinas' contemporaries that there was a fundamental incompatibility between the claim of ancient physics that something cannot come from nothing and the affirmation of Christian faith that God did produce everything from nothing. Furthermore, for the Greeks, since something must come from something, there must always be something – the universe must be eternal.

An eternal universe seemed to be incompatible with a universe created out of nothing, and so some mediaeval Christians thought that Greek sci-

[12] For a discussion of Aquinas' analysis of creation, see Steven E. Baldner and William E. Carroll, *Aquinas on Creation* (Toronto: Pontifical Institute of Mediaeval Studies, 1997). See also: William E. Carroll, "Aquinas and the Metaphysical Foundations of Modern Science," *Sapientia* 54 (1999), pp. 69-91.

[13] Too often, those who examine the distinction Aquinas draws between primary and secondary causality read Aquinas in the light of a Humean understanding of cause. See William A. Wallace, *Causality and Scientific Explanation*, 2 vols. (Ann Arbor: The University of Michigan Press, 1972), and Joseph De Finance, *Conoscenza dell'essere*, translated by M. Delmirani (Roma: Editrice Pontificia Università Gregoriana, 1993), pp. 332-423.

[14] This is what Polkinghorne calls "a kenosis (or emptying) of divine omnipotence."

[15] See William E. Carroll, "Thomas Aquinas and Big Bang Cosmology," *Sapientia* 53 (1998), pp. 74-95.

ence, especially in the person of Aristotle, ought to be banned, since it contradicted the truths of revelation. Aquinas, recognizing that the truths of science and the truths of faith could not contradict one another, since God is the author of all truth, went to work to reconcile the truths of Aristotelian science and Christian revelation.

The key to Aquinas' analysis is the distinction he draws between creation and change. The natural sciences, whether Aristotelian or those of our own day, have as their subject the world of changing things: from sub-atomic particles to acorns to galaxies. Whenever there is a change there must be something which changes. The Greeks are right: from nothing, nothing comes; that is, if the verb "to come" means a change. All change requires an underlying material reality.

Creating, on the other hand, is the radical causing of the whole existence of whatever exists. To cause completely something to exist is not to produce a change in something, is not to work on or with some already existing material. If there were a prior something which was used in the act of producing a new thing, the agent doing the producing would not be the *complete* cause of the new thing. But such a complete causing is precisely what the act of creation is. To create is to give existence, and all things are totally dependent upon God for the fact that they are. Creation out of nothing does not mean that God takes nothing and makes something out of "it." Rather, anything left entirely to itself, separated from the cause of its existence, would be absolutely nothing. To speak of creation out of nothing is simply to deny that there is any material cause in creation. Creation is not exclusively, nor even fundamentally, some distant event; it is the continuing, complete causing of the existence of whatever is. Creation, thus, is a subject for metaphysics and theology, not for the natural sciences.

Thomas Aquinas saw no contradiction in the notion of an eternal created universe. For, even if the universe had no temporal beginning, it still would depend upon God for its very being. There is no conflict between the doctrine of creation and any physical theory. Theories in the natural sciences account for change. Whether the changes described are biological or cosmological, unending or finite, they remain processes. Creation accounts for the existence of things, not for changes in things.

Aquinas thought that reason alone, in the discipline of metaphysics, could prove that the universe is created: that it is dependent upon God for its existence. The metaphysical understanding of creation leaves open the question of an absolute temporal beginning of the universe. Aquinas thought that neither metaphysics nor the natural sciences could determine

conclusively whether or not the universe is temporally finite. He accepted the temporal finitude of the universe only as a matter of faith. Here we have an excellent example of what Aquinas would call faith's adding to or perfecting what reason knows.

Although God is the immediate cause of all existing things, creatures are still true causes of effects. Aquinas' explanation is that creatures are the true causes of whatever comes to be either through motion or generation and that God is the cause of the being of all things, even of that which is produced through motion or generation. God is the constant cause of all being; creatures cause, as it were, only the determinations of being.

The natural sciences seek to discover real causes in the world. Aquinas argues that a doctrine of creation out of nothing, which affirms the radical dependence of all being upon God as its cause, is fully compatible with the discovery of causes in nature. God's omnipotence does not challenge the possibility of real causality for creatures, including that particular causality, free will, which is characteristic of human beings. Aquinas would reject any notion of a divine withdrawal from the world so as to leave room (a metaphysical space) for the action of creatures in such a way, for example, that God would be said to allow or to permit creaturely causality. Aquinas would also reject a process theology which denies God's immutability and His omnipotence (as well as His knowledge of the future) so that God would be said to be evolving or changing along with the universe and everything in it. For Aquinas, both views fail to do justice either to God or to creation. Creatures are, and are what they are (including those which are free), precisely because God is present to them as cause. Were God to withdraw, all that exists would cease to be. Creaturely freedom and the integrity of nature, in general, are guaranteed by God's creative causality, i.e., by God's intimate presence in all that He creates. Here is how Aquinas expresses it in the *Summa theologiae*:

> Some have understood God to work in every agent in such a way that no created power has any effect in things, but that God alone is the ultimate cause of everything wrought; for instance, that it is not fire that gives heat, but God in the fire, and so forth. But this is impossible. First, because the order of cause and effect would be taken away from created things, and this would imply lack of power in the Creator, for it is due to the power of the cause, that it bestows active power on its effect. Secondly, because the active powers which are seen to exist in things, would be bestowed on things to no purpose, if these wrought nothing through them. Indeed, all things

> created would seem, in a way, to be purposeless, if they lacked an operation proper to them, since the purpose of everything is its operation...We must therefore understand that God works in things in such a manner that things have their proper operation...[16]

As Simon Tugwell aptly puts it: "The fact that things exist and act in their own right is the most telling indication that God is existing and acting in them."[17] For God to be universal cause of being does not mean that God only provides what is common to being and thus allows secondary causes *by themselves* to provide the particular determinations of individual beings.[18]

[16] *Summa theologiae* I, q. 105, a. 5. In his earliest reference to this topic, Aquinas writes: "God is also the cause of these things, operating more intimately in them than do the other causes that involve motion, because He Himself gives being to things. The other causes, in contrast, are the causes that, as it were, specify that being. The entire being of any thing cannot come from some creature, since matter is from God alone. Being, however, is more intimate to anything than those things by which being is specified. Hence, it [being] remains even if those other things are removed, as is said in the *Book of Causes*, proposition 1. Hence, the operation of the Creator pertains more to what is intimate in a thing than does the operation of any secondary causes. The fact, therefore, that a creature is the cause of some other creature does not preclude that God operate immediately in all things, insofar as His power is like an intermediary that joins the power of any secondary cause with its effect. In fact, the power of a creature cannot achieve its effect except by the power of the Creator, from whom is all power, preservation of power, and order [of cause] to effect. For this reason, as is said in the same place of the *Book of Causes*, the causality of the secondary cause is rooted in the causality of the primary cause." *In II Sent*., d. 1, q. 1, a. 4, resp. We ought to note that in the passage from the *Summa theologiae* Aquinas' distinction between primary and secondary causality concerns formal and final causality as well as efficient causality.

[17] Simon Tugwell, *Albert and Aquinas: Selected Writings* (New York: The Paulist Press, 1988), p. 213.

[18] See Cornelio Fabro, *Participation et causalité selon S. Thomas d'Aquin* (Louvain-Paris: Nauwelarts, 1961), pp. 507ff. The alleged incompatibility between divine omnipotence and creaturely causality is the result, at least in part, of the failure to understand divine transcendence. Process theologians attack classical Christian theism "for its picture of a distant, lordly deity, incapable of being affected by the things of the world, standing at the summit of metaphysical hierarchies, and reinforcing their oppressive structures." They "tend to define the issues in terms of a debate between rival metaphysical systems, with the utterly transcendent, omnipotent God of classical theism set against the more immanent, collaborative God of process thought, who is (for Whitehead) an actual occasion or (for Hartshorne, Ogden, Cobb, and Griffin) a society of actual occasions, but at any rate one of the things in the world in genuine interaction with the others." William Placher, *The Domestication of Transcendence* (Louisville, KY: Westminster Press, 1996), pp. 1 and 9.

Proponents of what has been termed "panentheism" criticize "classical Western the-

In our own day, various intellectual schemes which seek to make room for the agency of creatures or which find theological significance for divine action in terms of the "ontological openness" of quantum mechanics and chaos theory fail to recognize the profound metaphysical point that divine causality transcends any other category of causality.

When Aquinas speaks of causality he employs a much richer sense of the term than we tend to use today. Whereas contemporary thinkers have come to view causality in terms of a kind of "necessary consequentiality" between events, Aquinas understood causality in terms of metaphysical dependence.[19] As part of the philosophy of nature connected to the rise of "modern science," two of the four causes of Aristotelian science, the final and the formal, were considered irrelevant. Furthermore, to the extent that the natural sciences came to be seen as depending exclusively on the language of mathematics, only that which was measurable would fall within their explanatory domains.[20]

Even the notion of agent or efficient causality underwent a profound change from the Aristotelian sense. It was conceived "exclusively in terms

ism" for understanding the world as being "ontologically outside of God," and, thus, as presenting significant difficulties for making sense of God's action in the world. [P. Clayton, *God and Contemporary Science* (Edinburgh: Edinburgh University Press, 1997), p. 100.] Their concern is to fashion a theology consistent with biblical revelation and the insights of contemporary science and philosophy, but their criticism of classical theism does not do justice to the position of Aquinas.

[19] "Il titolo di questo libro richiama una nozione, 'causa,' che suggerisce al lettore contemporaneo contenuti concettuali per qualche aspetto sostanzialmente diversi da quelli che evocava nel lettore medievale. Difatti per i contemporanei il termine 'causa' indica per lo più la sola idea di consequenzialità necessaria...Per il lettore medievale, invece, accanto all'idea di una connessione di fatto, il concetto di 'causa' trasmette quella di un ordinamento metafisico...La causa, in questo modo, è superiore all'effetto; e poiché è principio della sua sussistenza in essere, è principio anche della sua intelligibilità." Cristina D'Ancona Costa, "Introduzione," in Tommaso D'Aquino, *Commento al Libro delle Cause* (Milan: Rusconi, 1986), p. 7.

[20] Mario Bunge points out the important role that empirical science has played in this shift in our understanding of causality: "The Aristotelian teaching of causes lasted in the official Western culture until the Renaissance. When modern science was born, formal and final causes were left aside as standing beyond the reach of experiment; and material causes were taken for granted in connection with all natural happenings... Hence, of the four Aristotelian causes only the efficient cause was regarded as worthy of scientific research." Mario Bunge, *Causality and Modern Science* (New York: Dover, 1979), p. 32. See William A. Wallace, O.P., *Causality and Scientific Explanation*, 2 vols. (Ann Arbor: University of Michigan Press, 1972), vol. 2, p. 246.

of the force or energy that moved the fundamental parts of the universe."[21] In the eighteenth century, David Hume called into question even this narrow idea of efficient causality. Since the supposed influence of a cause upon its effect was not directly evident to sense observation, Hume concluded that the connection between cause and effect was not a feature of the real world, "but only a habit of our thinking as we become accustomed to see one thing constantly conjoined to another." Causality became not a property of things but of thought; it "was no longer an *ontological* reality in the world outside ourselves, but an *epistemological* property of the way we think about the world. [Thus,] the hallmark of causality was found in the epistemological category of *predictability* rather than the ontological category of *dependence*."[22]

One of the consequences of viewing causality *exclusively* in terms of a physical force is that divine causality, too, comes to be seen in such terms.[23] To conceive God's causality in this way is to make God a kind of competing cause in the world. To view the world as functioning in terms of an ordered regularity of mechanical causes seemed to mean that there was no room for any kind of special divine action.[24] Starting from this kind

[21] Michael J. Dodds, "The Doctrine of Causality in Aquinas and *The Book of Causes*: One Key to Understanding the Nature of Divine Action," paper delivered at the Thomistic Institute, University of Notre Dame, July 2000. I am grateful to Professor Dodds for his analysis of the narrowing of the notion of causality, which I have used in this section of my paper.

[22] *Ibid.*

[23] As Philip Clayton has observed: "The present-day crisis in the notion of divine action has resulted as much as anything from a shift in the notion of causality." *God and Contemporary Science*, *op. cit.*, p. 189.

[24] "The more man is imbued with the ordered regularity of all events the firmer becomes his conviction that there is no room left by the side of this ordered regularity for causes of a different nature. For him neither the rule of human nor the rule of divine will exists as an independent cause of natural events." Albert Einstein, *Out of my Later Years* (New York: Wisdom Library, 1950), p. 32. Keith Ward also observes: "The scientific world-view seems to leave no room for God to act, since everything that happens is determined by scientific laws." Keith Ward, *Divine Action* (London: Collins, 1990), p. l. Langdon Gilkey explains this reluctance of contemporary theologians to speak of divine intervention: "Thus contemporary theology does not expect, nor does it speak of, wondrous divine events on the surface of natural and historical life. The causal nexus in space and time which Enlightenment science and philosophy introduced into the Western mind and which was assumed by liberalism is also assumed by modern theologians and scholars; since they participate in the modern world of science both intellectually and existentially, they can scarcely do anything else." Langdon Gilkey, "Cosmology, Ontology and the Travail of Biblical Language," in Owen C. Thomas, ed.,

of analysis, several contemporary theologians, as we have seen, have found such room for divine action, what Polkinghorne calls "room for divine manoeuvre," in the new scientific view of the world set forth in quantum mechanics and chaos theory.

In various contemporary accounts of divine action there is a special concern to locate the "causal joint," that particular point or way that divine causality can be conceived of as interfacing with the physical world. The concern for finding such a "causal joint" proceeds from assumptions about divine causality which are problematic.[25] For even if we grant that contemporary physics affirms a radical indeterminism in nature, any analysis of God's action in the world will be impaired if we restrict our notion of cause to the categories of matter, energy, and force. It is important to note, however, that the narrowing of the notion of causality, in the thought of Hume and others, to which I have referred, has occurred in the philosophy of nature, not in the empirical sciences themselves. When scientists adopt such limited or restricted notions of cause, they are operating in a broader arena of analysis than that of the empirical sciences themselves. In a sense, natural philosophy is a more general science of nature than any of the specialized sciences; it examines topics such as the nature of change and time, the role of mathematics in the investigation of nature, and related questions.

God's Activity in the World: the Contemporary Problem (Chico, California: Scholar's Press, 1983), p. 31.

[25] As Philip Clayton explains, "If one is to offer a full theory of divine agency; one must include some account of where the 'causal joint' is at which God's action directly impacts on the world. To do this requires one in turn to get one's hands dirty with the actual scientific data and theories, including the basic features of relativity theory, quantum mechanics and (more recently) chaos theory." Philip Clayton, *God and Contemporary Science*, p. 192. The difficulties of discovering such a "causal joint," however, are evident in the work of Arthur Peacocke who maintains that "the continuing action of God with the world-as-a-whole might best be envisaged...as analogous to an input of information rather than of energy." The problem with this notion, as Peacocke recognizes, is that in physics "any input of information requires some input of matter/energy." Such matter/energy input on God's part, however, smacks of interference with the order of the world. Peacocke concludes that he has located, but not solved, the problem of the "causal joint": "How can God exert his influence on, make an input of information into, the world-as-a-whole without an input of matter/energy? 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 be the right place in which to locate the problem..." Arthur Peacocke, *Theology for a Scientific Age: Being and Becoming – Natural, Divine and Human* (Minneapolis, MN: Fortress Press, 1993), pp. 149-151, 160-161, 164.

One obstacle to a return to the rich view of causality found in the thought of Aquinas, including his profound understanding of the differences between the explanatory domains of creation and the natural sciences, is the view that his theological and philosophical thought is too closely tied to a science of nature which we reject as false. Interpretations of modernity depend in important ways on analyses of the Scientific Revolution of the seventeenth century. In particular, the materialism, mechanism, and reductionism so often associated with modern science has its roots in a faulty philosophy of nature supported by an interpretation of the history of science.[26] The understanding of the rise of modern science as involving a rejection of Aristotelian science[27] has led many to ignore the profound truths about nature, human nature, and God which are found in Aristotelian and Thomistic thought.

If there is a fundamental incompatibility, or incommensurability, between Aristotelian science and modern science, then any theological or philosophical reflection rooted in or employing principles from Aristotelian science must either be rejected or radically reformulated. Often I partici-

[26] Examples of such philosophical claims are readily evident in many texts. More than twenty-five years ago, the French biologist Jacques Monod remarked: "Anything can be reduced to simple, obvious, mechanical interactions. The cell is a machine; the animal is a machine; man is a machine." (Jacques Monod, *Chance and Necessity: An Essay on the Natural Philosophy of Biology.* New York: Knopf, 1974, p. ix) Or consider the well-known comment by Richard Dawkins, author of *The Selfish Gene*, who claims that a human being is not a cause but an effect, and that life and mind are merely the outcome of genes that "swarm in huge colonies, safe inside gigantic lumbering robots."(Richard Dawkins, *The Selfish Gene*, New York: Oxford University Press, 1976, p. 21) In *River Out of Eden: A Darwinian View of Life*, Dawkins is not afraid to draw the following conclusion: "The universe we observe has precisely the properties we should expect if there is, at bottom, no design, no purpose, no evil and no good, nothing but blind pitiless indifference...DNA neither knows nor cares. DNA just is. And we dance to its music." (New York: Basic Books, 1995, p. 133). Sir Francis Crick, co-discoverer of the double-helix structure of the DNA molecule, writes at the beginning of *The Astonishing Hypothesis*: "The Astonishing Hypothesis is that 'You,' your joys and your sorrows, your memories and your ambitions, your sense of personal identity and your free will, are in fact no more than the behavior of a vast assembly of nerve cells and their associated molecules." (New York: Scribner, 1994)

[27] The commonly accepted narrative of the Scientific Revolution sees a fundamental discontinuity in the history of science which heralds the birth of modern science. For an excellent survey of various interpretations of the Scientific Revolution, see H. Floris Cohen's *The Scientific Revolution: A Historiographical Survey* (1994). David Lindberg's introductory essay on conceptions of the Scientific Revolution in D. Lindberg and R. Westman (eds.), *Reappraisals of the Scientific Revolution* (1990) is also excellent.

pate in conferences on the relationship between religion and science in which speakers refer to the "Newtonian settlement" as the basis for modern philosophy and theology.[28] This "settlement" tends to rule out appeals to Aristotelian and Thomistic natural philosophy since, so the argument goes, such a philosophy of nature has been rendered false[29] by modern science. This helps to explain why in the seventeenth and eighteenth centuries it was apparent to many that *only* a mechanistic philosophy of nature could meet the evidence of modern science.[30] More frequently today process thought is urged as providing the necessary philosophical complement to the natural sciences. Form and matter, substance and accident, teleology, and the like (concepts which are at the heart of Thomistic natural philosophy) are thus all seen as part of a view of the world which, thanks to the Scientific Revolution, we know is wrong.

An elaborate analysis of the Scientific Revolution, especially an investigation of questions of continuity and discontinuity in developments in the natural sciences in this period is well beyond the scope of this essay. Here I can only sketch in outline a way to look at the developments in science at the dawn of the modern age which does not involve a radical break with the past. The tremendous advances in the role of mathematics in the study of nature, characteristic of the Scientific Revolution, do not require, I think, a rejection of Aristotelian and Thomistic natural philosophy. Thomas Aquinas, following Aristotle, distinguishes between the natural sciences and mathematics in terms of their objects of study as well as in terms of the different ways in which these objects are known. The natural sciences study what exists in matter and in motion *precisely* as these things exist in matter and motion. Man cannot be studied, as man, distinct from flesh and bones. Man cannot be understood without his materiality. Mathematics studies those dimensions and quantities which *exist* in sensible matter, but which can be *known* separate from sensible matter. Man, through a special process of intellectual abstraction,

[28] It is important to note that those who speak of such a "settlement" also argue that contemporary science, especially relativity theory and quantum mechanics, have altered this settlement so radically that theologians and philosophers must adjust their understanding of nature, human nature, and God to take into consideration the new scientific perspective(s).

[29] For those who dislike the notion of "truth" and "falsity" in discussions of claims about the world, the argument is simply that a new paradigm has replaced an old one.

[30] Indeed, early proponents of mechanism, especially in the seventeenth century, saw in it a way to reconcile their belief in God with the insights of Newtonian science.

has the capacity to understand shapes and numbers independently from the material bodies in which they exist.[31]

For Aquinas, mathematics does not provide a *deeper* explanation of the world of nature than do the natural sciences; nor does mathematics provide the true principles of scientific inquiry for the natural sciences. The natural sciences have an autonomy appropriately their own.[32]

According to Aquinas, although mathematics and the natural sciences are autonomous and distinct sciences, one may apply mathematical principles to the study of natural phenomena. Such applications occur in neither the science of mathematics, nor in physics. They constitute mixed sciences: types of knowledge that are intermediate between what we today might term "pure" mathematics and a more general science of nature.[33] Referring to such a mixed science, Aquinas writes: "it does not belong to the mathematician to treat of motion, although mathematical principles can be applied to motion...The measurements of motions are studies in the intermediate sciences between mathematics and natural science."[34]

[31] Aquinas' most important work in this respect can be found in his *Commentary on Boethius' 'On the Trinity'* (questions 4 and 5) and in his commentary on the second book of Aristotle's *Physics*.

[32] The importance of mathematics in the thought of Galileo and Newton has led some scholars such as E. A. Burtt and Alexandre Koyré to see the Scientific Revolution as a radical shift in metaphysics: a return, if you will, to the heritage of Plato and a rejection of Aristotle. Such an interpretation misses an important point in the mediaeval understanding of the relationship between mathematics and physics.

[33] Aristotle, in the second book of the *Physics*, recognizes the legitimacy of such intermediate sciences, what he considers to be *in some sense* branches of mathematics which come nearest to the study of nature: optics, harmonics, and astronomy.

[34] *Commentary on Boethius' 'On the Trinity'* q. 5, a. 3, ad 5 [*The Division and Methods of the Sciences*, translated by Armand Maurer (Pontifical Institute of Mediaeval Studies, 1963), p. 36.] See also, *In II Phys.* lec. 3, n. 8. "So there are three levels of sciences concerning natural and mathematical entities. Some are purely natural and treat of the properties of natural things as such, like physics...Others are purely mathematical and treat of quantities absolutely, as geometry considers magnitude and arithmetic number. Still others are intermediate, and these apply mathematical principles to natural things; for instance, music, astronomy, and the like. These sciences, however, have a closer affinity to mathematics, because in their thinking that which is physical is, as it were, material, whereas that which is mathematical is, as it were, formal. For example, music considers sounds, not inasmuch as they are sounds, but inasmuch as they are proportionable according to numbers; and the same holds in other sciences. Thus they demonstrate their conclusions concerning natural things, but by means of mathematics." (Maurer, pp. 37-38). For an insightful discussion of this treatise, see Stephen L. Brock, "Autonomia e gerarchia delle scienze in Tommaso d'Aquino. La difficoltà dellla sapien-

The application of mathematical principles to the study of natural phenomena is never a substitute for the natural sciences themselves which have as their object the study of physical bodies in their full reality. Principles of mathematics, although applicable to the study of natural phenomena, cannot explain the causes and true nature of natural phenomena.

It seems to me[35] that we can best understand the history of science in the fourteenth through the seventeenth centuries – and, indeed, beyond to our own time – if we recognize that some of the greatest accomplishments in the sciences have taken place in those intermediate sciences between mathematics and the natural sciences. The careful distinctions drawn by Thomas Aquinas frequently have been lost in the midst of the great advances such a mathematical approach has achieved.[36]

Once we understand the nature of mathematics, the natural sciences, and the intermediate sciences – an understanding present in the thought of Aristotle, and reaffirmed by Thomas Aquinas – then, I think, we can see a fundamental continuity in the history of science from the time of Aristotle to the present. Although ancient and mediaeval thinkers were not very concerned with the application of mathematics to the study of nature, still, they did recognize the validity of the use of mathematics in investigating nature. Such a perspective on the Scientific Revolution frees us from the false view that one must choose between Aristotle and the great advances of modern science.[37]

za," in *Unità e autonomia del sapere. Il dibattito del XIII secolo*, ed. Rafael Martínez , pp. 71-96 (Rome: Armando Editore, 1994).

35. And here I am following in the footsteps of James Weisheipl, William Wallace, and others.

36. The confusion is already in Descartes, who called inertia the first law of nature, rather than recognizing it, as Newton did, as a mathematical principle of natural philosophy.

37. We would also be emancipated from the false exaggeration of the importance of mathematics, an exaggeration which has encouraged many to force all the sciences – natural and social – into the Procustean bed of mathematics, belittling or tending to ignore what cannot be timed, weighed, measured, or counted.

One of the great achievements of Albert the Great and Thomas Aquinas was their clear demonstration of the autonomy of the natural sciences: an autonomy, by the way, with respect to theology and to faith, as well as with respect to mathematics. They had no doubt that the physical universe is intelligible and that it is, therefore, an appropriate object of scientific investigation. The natural scientist explains change in its many forms: generation and destruction, locomotion, alteration, and the like. A science of generation and destruction, locomotion, and alteration must provide explanations in terms of the proper causes for these changes. The principles used in these explanations are not

The philosophical baggage of a mechanistic and materialistic natural philosophy which is often associated with modern science is the product of *philosophical* traditions in the seventeenth century and beyond. Mechanism and materialism represent a radical rejection of Aristotelian and Thomistic natural philosophy, but mechanism and materialism remain excess baggage, *not required* in order to accept the advances in our understanding of the world which are the legacy of Galileo and Newton. Although many historians, philosophers, and theologians see modern science as providing, ultimately, a challenge to the God of traditional religion, such a judgment rests on questionable interpretations of the Scientific Revolution as well as on a failure to appreciate the theological and philosophical heritage of the Middle Ages, according to which divine action does not challenge the appropriate causal autonomy of the natural world.

The point I wish to emphasize as a result of this brief excursion into the historiography of the Scientific Revolution is that particular views which embrace a radical discontinuity between "modern science" and Aristotelian and mediaeval science lead many to disregard or summarily to reject important insights into the nature of causality, divine and that of creatures, forged by thinkers such as Thomas Aquinas.

Misinterpretations of the Scientific Revolution may have also tempted some in the Thomistic tradition to retreat from the arena of natural philosophy to bask in the seemingly safer and ethereal realm of metaphysics. The history of science can help us distinguish among the advances of modern science, the mechanistic and materialist natural philosophy which has accompanied these advances, and the principles of Thomistic natural philosophy which still can lead to a deeper and more complete understanding of nature, human nature, and God.[38]

mathematical. And it does not matter whether we are speaking of productive, practical, or theoretical science. How can points, lines, surfaces, numbers, or equations – principles of mathematics – how can these cause the construction of houses or the writing of a poem? How can points, lines, surfaces, numbers or equations cause men to fashion constitutions, to engage in commerce or to live virtuously? How can points, lines, surfaces, numbers or equations cause the birth of an animal, the growth of an acorn into an oak tree, the movement of either planets or subatomic particles? As Albert and Thomas clearly understood, scientific explanations – explanations in terms of causes – employ the principles appropriate to each science. Although mathematics is clearer and more certain than the natural sciences, we must resist the temptation to regard mathematics either as the only true science or as a substitute for the natural sciences.

[38] Much work needs to be done by those in the Thomistic tradition to incorporate the discoveries of modern science into a broader philosophy of nature. Three authors

Thomas Aquinas' understanding of creation and divine causality allows us to avoid various contemporary attempts to accommodate the discoveries of the natural sciences by denying God's omnipotence, omniscience, and timelessness. Aquinas provides us as well with a robust view of divine action which does not require some form of metaphysical indeterminism in the world: an "ontological openness" so that God's acts might not "interfere" with nature. However impressive the advances in science which began in the seventeenth century, these advances do not challenge the fundamental insights about creation and science reached by Thomas Aquinas.

who have worked in this area are: Benedict Ashley, *Theologies of the Body*; Richard Connell, *Substance and Modern Science*; and William Wallace, *From a Realist Point of View* and *The Modeling of Nature.*