RELIGION AND THE THEORIES OF SCIENCE: A RESPONSE TO BARBOUR

by Robert John Russell

Abstract. This paper offers a detailed response to "Religion and the Theories of Science" in Barbour's Gifford Lectures I. Topics include: complementarity, indeterminacy, parts and wholes, and Bell's theorem in quantum theory; metaphysical issues raised by relativity theory and thermodynamics, principally the problem of temporality and "top-down" versus "bottom-up" causality; design arguments and the origins of the universe in astronomy and creation; and God's action in the context of evolution and continuing creation. Areas of agreement and disagreement between Barbour and myself over philosophical and theological implications are presented, and endnotes indicate further areas of conversation.

Keywords: astronomy; Bell's theorem; "bottom-up" causality; complementarity; contingency; creation theology; design argument; evolution; genetic mutations; God's action; holism; indeterminism; origins; quantum theory; realism; relativity theory; temporality; thermodynamics; "top-down" causality.

My assignment involves responding to three chapters of Ian Barbour's "Religion and the Theories of Science" in his recent Gifford Lectures I (Barbour 1990). I will give short responses to a variety of topics in the first chapter (chapter 4), then choose a key topic from the second and from the third chapter (chapters 5 and 6) for a longer response.

CHAPTER 4: PHYSICS AND METAPHYSICS

I. Quantum Theory. Barbour raises four areas for discussion in his initial presentation of quantum theory: complementarity, indeterminacy, parts and wholes, and Bell's theorem. In each case

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he takes a position which contributes later in the chapter to his conclusions about the metaphysical implications of physics. I will briefly summarize and respond to each of these positions in turn.

Drawing on recent work by Henry Folse, Barbour points out that while Niels Bohr is often taken as an instrumentalist, he can perhaps best be understood as a critical realist. Though I agree with the Barbour/Folse assessment, I want to stress the challenge complementarity poses to our conception of that underlying reality. How are we to think of that which appears as both wave and particle in the same experiment, or whose causal explanation cannot be understood in the language of space and time? Will either Aristotle with his notion of *potentia* or Whitehead with his notion of actual occasion be of significant help here?

Barbour urges us to search for new unifying models which *overcome* the problem, suggesting they may already be available. I agree. For example, one such approach is taken by research into a nonlocal hidden variables interpretation (Redhead 1987; Cushing and McMullin 1989). Alternatively, we may need to look beyond quantum physics to its merger with special relativity in quantum field theory (see, e.g., Teller 1995). Still, it remains to be seen whether either quantum theory or quantum field theory admits an ontology capable of a critical realist interpretation.

Barbour interprets the statistical character of quantum physics as a sign of ontological indeterminacy in nature. It is entirely different from chance in classical physics, which is merely a cover for our ignorance of the underlying causes.[1] I agree with Barbour's interpretation, though the challenge of nonlocality to critical realism is powerful (see below).

Quantum theory poses a pivotal challenge to the reductionism associated with classical physics, since its description of complex systems (including even such simple examples as a helium atom) cannot be reduced to the description of its parts and their simple addition. "The helium atom is a total pattern with *no distinguishable parts*" (p 105; Barbour's italics). I agree with Barbour, but again I must raise the ontological question: How are we to describe the ontology of the whole, the parts, and their relationship from a critical realist perspective? Is there a genuine alternative to either (1) ontological reductionism, in which complexity at higher levels in nature may lead to an epistemological hierarchy but does not reveal the ontologically "new," or (2) ontological levels, in which the epistemic hierarchy undercuts an appeal to "one world" and suggests a dualistic or even multileveled world which Barbour correctly rejects?

With roots in the early debate between Einstein and Bohr, Bell's theorem and the experiments of Aspect and others force us to reject either consistency with special relativity (called "locality") or realism. As Barbour sees it, we must choose between local critical realism and nonlocal classical realism.[2] I disagree with Barbour's assessment of the choice. Instead I believe we are forced into an even more egregious choice, namely between nonlocal realism and local antirealism. In either case, the challenge to Barbour, as to the rest of us who defend "locality" (i.e., special relativity) in spite of quantum correlations with spacelike separations, and who do so while supporting realism (even if "critically"), is to produce a metaphysical system through which the "nonseparability" ontology of quantum systems, their radical wholeness, can be made intelligible. Again, this is an outstanding and unsolved problem in our field.

II. Relativity and Thermodynamics. In this section, Barbour discusses three topics: space, time, and matter; the status of time; and order and disorder. Barbour rejects three "dubious claims" about the status of time in relativity: that it is illusory; that reality is mental; and that relativity supports relativism. Instead of the block universe which spatializes time, Barbour supports the temporalization of space. "Dynamic events, not unchanging substances, are now taken to constitute reality." Instead of an idealist philosophy and pervasive consciousness, Barbour supports an objectivist philosophy and ontological interconnectedness. Rather than overthrowing all absolutes, science has exchanged old ones (such as space and time) for new ones (such as spacetime). The universe is "dynamic and interconnected," including a more complex combination of both wholeness and separateness. God's knowledge of the world is not affected by the limitations of the speed of light, since God is immanent in all events. Finally, thermodynamics introduces entropy and disorder into our understanding of natural processes, giving them an irreversible orientation in time. Even simple physical systems display self-organization, moving from simpler to more complex levels of order, and calling into question determinism and reductionism.

In my opinion (Russell 1994a), however, the problem of temporality in light of special relativity is far more complex than the choice between dynamic (or flowing) time and the static (or block) universe conveys. The problem revolves around two issues.

First, the downfall of simultaneity tends to undercut the "flowing time" view. On the one hand, given a realist perspective, the objectivist implications of a timelike spacetime interval and the

irreducibility of the relativistic topology of spacetime to the classical topology of flowing time undercut arguments for flowing time and a dynamic universe. Obviously classical physics can be seen as a predictive approximation in the limit of low velocities. Still, this cannot help the realist who is committed to explanatory power when one is confronted with topological irreducibility. Put more directly, flowing time requires a unique, global, physical present, and there is none in nature. We have yet to take the full measure of this fact.

On the other hand, the block universe model fails to capture the subtle differences in the ontology of spacetime bequeathed it by the light-cone structure, which gives to all events a highly complex set of temporal (or causal) relations. Some of these (those that are timelike) are unambiguous; others (those that are spacelike) *are* deeply ambiguous. This fact undermines a naive understanding of nature as timeless or purely spatial, and with it the block universe.

Likewise there is no basis for distinguishing the ontological status of any event from any other as "actual," though every event has a unique relation to all the others in its light-cone domains. Thus, while timelike order is possible, timelike orientation is ephemeral. This tells against both flowing time and a block universe interpretation, since there is no reason to claim that some events are "yet to come" and others "already past," *nor* is there any reason not to![3]

I doubt whether thermodynamics can offer much help for a realist philosophy since it is not a fundamental theory; indeed, it is not even relativistically invariant in its standard formulation. The spontaneous occurrence of order in dissipative systems suggests an antireductionist argument (though not one against determinism), but such order in the context of thermodynamics is surely the result of a mere combination of parts. Only if thermodynamic complexity can be given an ontological interpretation as found in quantum physics will it be promising here, and this seems to me highly unlikely. Is the richness of temporality and our inability to find an adequate basis for it in physics an example of an emergent in nature, or is it an example of an idle philosophical dispute which lacks any empirical paydirt?[4]

Finally, the issue of God's knowledge of and influence on the universe in light of relativity is extraordinarily complex. Charles Hartshorne underscored the challenge relativity raises for process theology (Hartshorne 1967, 92–95). Barbour suggests that if divine omnipresence is combined with divine immanence, and if God's influence is consistent with the complex causality of special relativity, the problem can be resolved (Barbour 1990, 112; see in particular note 29). In what I take as an extension of this kind of approach, John

Polkinghorne his pointed out that if the microwave background provides a cosmological reference frame for global simultaneity, then God could act in this cosmic "present" without violating special relativity (Polkinghorne, private correspondence, 1995). This suggestion deserves further reflection.

III. Metaphysical Implications. In this section, Barbour deals with the role of mind, the issues of life, freedom, and God, and physics in relation to Eastern mysticism. I agree with Barbour in his criticisms of those who use physics in an unnuanced way as a basis for a philosophical idealism in which mind is given unequivocal priority over matter. I also agree with his criticisms of Fritjof Capra, where similarities between physics and Eastern mysticism have been overstressed and differences—as well as differences within mysticism itself—have been ignored.

I am most interested in Barbour's comments on life, freedom, and God in this section. Barbour points out that, contrary to first appearances, quantum theory is highly relevant to biological systems and thus to evolution, noting the importance of mutations in variation. He notes that quantum indeterminacy at least allows for human freedom, although it is certainly not to be identified with it. This is particularly important since a Newtonian framework seems to make free agency unintelligible. But does quantum indeterminacy allow God to act in the world? Here Barbour objects to Pollard's formulation, since it would give God total sovereignty over every event, leading to predestination, the challenge to free will, and the problem of evil. In addition, chance once again becomes a form of human ignorance, but now ignorance of God's sovereign action, and the proposal ignores top-down causality—God acting at the level of human self and history. Instead, God acts at every level and God's actions take into account law and chance, allowing chance to be "as real for God as it is for us." We will return to these issues in reference to chapter 6.

I agree with Barbour that we need both "top-down" and "bottom-up" arguments about causality, and I agree that free will transcends the categories used in physics, including indeterminacy. I would even press the latter point further by raising a general criticism of "levels" theory, drawing here on Tillich's "case against levels" and his use of the metaphor, the "multidimensional unity of life," and his insistence that freedom takes its place in relation to destiny, not chance. Still, without quantum chance as evidence of ontological indeterminacy, it is hard to see how human—or divine—agency really makes sense. This is especially true when applied to the early

universe before there were higher levels as required for divine "top-down" causality to work. I want to broaden the implications of quantum chance, however, by recognizing that the ordinary world of experience is, in a very real way, the direct result of quantum physics, since the "classical world" emerged from the "quantum world" during the very early history of the universe. I will return to the implications of quantum indeterminacy when I discuss Barbour's views on evolution and continuing creation.

CHAPTER 5: ASTRONOMY AND CREATION

I will now shift the style of my response by choosing two major themes in chapter 5 and give a more detailed response to them, passing over many other important points (see the Notes for details).

I. Design. According to Barbour, the anthropic principle forces many scholars to choose between two kinds of response: many worlds and design. Instead, I propose that a better response starts by placing the many-worlds and design arguments in a dialectical relation (Russell 1989). The many-worlds response tends to undercut the design argument by claiming that all possible universes exist, each characterized by a different value of the fundamental constants, and this serves to explain our existence without appeal to a Designer. But the many worlds argument, in turn, raises us to the next level of abstraction, and here a design-type argument reappears. Thus one asks why all these universes obey the same laws of physics. Are these laws the object of God's design? Do they require a Designer to explain them? But this, in turn, takes us to a still higher level of abstraction, for we can construct a many-worlds argument characterizing all possible sets of laws of nature. But again we see design implications, since one can ask why the set of all possible laws is governed by the same kind of logic. Did God choose the logic which governs them? Or are all possible kinds of logic available in a higher form of the many-worlds argument? Now we can ask a different kind of question about the entire preceding discussion: Does this interplay between design and many-worlds at each level continue indefinitely, or does it end? Is it, too, evidence of design, but now at an even more inclusive level?

Or perhaps the entire argument, including the simplest form of the many-worlds argument, is specious! According to William Stoeger (1993), many-worlds arguments are suspect for several reasons. They appeal to infinite sets of universes beyond any conceivable

evidence to explain the existence of our universe. Moreover, they assume that the laws of nature are prescriptive and not just descriptive. At best, they only explain the way our universe exists and not the existence of our universe per se. Is not God in any case required for a complete explanation of existence, as philosophical theology has routinely argued?

Barbour's discussion of contingency and its relation to design raises additional important questions. According to Wolfhart Pannenberg, "the existence of the world as a whole and of all its parts is contingent" (Pannenberg 1988; see also Russell 1994b). I have suggested a typology of kinds of contingency entailed in Pannenberg's argument. This includes ontological contingency (why there is anything at all), both in its global form (why there is a universe), and local form (why individual things persist in being); existential contingency (why things exist as they do), again both globally and locally; and nomological contingency (why the laws of nature are as they are, why they are first instantiated at a particular point in time, and so on).

Here I want to stress that these forms of contingency are not necessarily independent. Constraints can exist which lessen *their* contingency by introducing an element of necessity among them. In particular, I want to underscore the role of the speed of light, c, and Planck's constant, h, in both global and local existential contingency. The precise value of these constants characterizes the universe as a whole, or what I am calling global existential contingency, as suggested by the anthropic principle just discussed. They also affect the detailed character of the local processes of nature, from molecular biology to ecology, since the size of Planck's constant allows a classical world to arise within the context of a relativistic quantum world (and it did so arise in the very early quantum universe!). In effect, if contingency is an aspect of the doctrine of creation, reflecting the freedom of God in creating *this* universe, we must conclude that God is not *entirely* free: God's choice of the values of these fundamental constants, once taken, determines not only the gross properties of the universe as a whole but also the local features in tremendous detail. Hence, instead of Pannenberg's formulation of the problem, we might prefer to claim that while the existential character of the universe is contingent, this contingency is constrained by the intrinsic codetermination of its global and local character.

II. Origins. Next we turn to the discussion of origins. If science were to present fairly compelling evidence that the universe

began at $t = 0$, that is, that it has a finite past, should this be important to Christian theology? If so, does this require us to reflect on theological method as well as content? These questions of content and of method point to foundational dimensions in theology. I believe we can learn a great deal about the kind of answer we should give by studying the way in which Barbour's response came about historically.

In recent work (Russell 1993) I traced Barbour's position in both *Issues* and the Gifford Lectures back to Langdon Gilkey's important 1959 book *Maker of Heaven and Earth*. In *Maker*, Gilkey tells us that the idea of an " 'originating' activity of God" has historically taken two distinct forms: ontological origination, which means that ". . . God originates the *existence* of each creature out of nothing, whatever its position in the time scale," and historical/empirical origination, which means " 'originating' in the sense of founding and establishing at the beginning (Gilkey 1959, 310). He attributes this distinction to Thomas Aquinas (Gilkey 1959, 313) and, in a move which casts long shadows over all that is to follow, he interprets it as a *strict dichotomy*. Gilkey then accepts the ontological origination as theologically appropriate, but he rejects historical origination. Knowledge about a first moment of time cannot be a valid part of theology since theology does not contain *any* "facts" about the natural order.[5]

Barbour's views on $t = 0$ are rooted in the position Gilkey set out in *Maker*. In both *Issues* and the Gifford Lectures, three critical points emerge: (1) Barbour accepts the sharp ontological/historical distinction proposed by Gilkey; (2) he argues that the ontological interpretation carries the central meaning of *ex nihilo*; and (3) he concludes that $t = 0$, being empirical, plays no significant role in the *ex nihilo* tradition.[6]

I believe we can move beyond the Gilkey/Barbour position by recognizing that Gilkey made an unnecessary and costly premise: that ontological and empirical origination form a sharp dichotomy. Instead, I propose we reintegrate historical/empirical language into the broader context of ontological origination, thus giving a factual domain to which ontological origination can be related without literalization or equivocation. If science supports a universe with a finite age, as the Big Bang suggests, this can count as empirical evidence in support of ontological origination. Ontological dependence is thus the *crucial*, but not the *exhaustive*, meaning of creation. To use a legal analogy, the Big Bang serves as a character witness but not as an eyewitness for creation.

To make this case stronger, I propose we adopt a new methodology

for theological research, one which actually was anticipated by Barbour himself in 1974 in *Myths, Models and Paradigms* (Barbour 1974, chs. 6, 7) and has been developed in detail by both Nancey Murphy (1990) and Philip Clayton (1989). These scholars appropriate current research in philosophy of science for the purposes of theological method, focusing specifically on Imre Lakatos (1978, 8–101). Following them, I propose we structure the doctrine of creation *ex nihilo* and its relation to data in cosmology in terms of a Lakatosian research program. This will include a central, or "core," hypothesis, "*creatio ex nihilo* means ontological origination," surrounded by a protective belt of auxiliary hypotheses, namely, "ontological origination entails finitude," "finitude includes temporal finitude," and "temporal finitude includes past temporal finitude." In this way evidence for empirical origination from contemporary science, such as the Big Bang offers in terms of $t = 0$, could be related to a core theological hypothesis, such as *creatio ex nihilo*, in such a way as to allow it to confirm the hypothesis without the evidence being directly identified with it.

I want to emphasize, though, that this method allows for disconfirmation as well as confirmation. For example, the infinite size and the unending future of the open Big Bang scenario works against the finitude of creation, as does the infinite past entailed by some proposals in quantum gravity. Moreover, one really should use Lakatosian methodology to compare several competing theological research programs, each of which attempts to relate *creatio ex nihilo* to cosmology in its own way, and assess which program is most progressive by the way it predicts novel facts and avoids *ad hoc* moves. In this way, if we are willing to risk disconfirmation and enter into an ongoing interaction with science, we can move theology out of its closed hermeneutical circle and allow it to make cognitive contact with empirical knowledge.

Chapter 6: Evolution and Continuing Creation

One topic involves many of the issues raised in this chapter: Can evolutionary theism avoid an incipient deism by including God's action in specific natural events without involving us in an interventionist strategy? In recent work I have developed a positive response to this question, which I will very briefly summarize here.

My claim rests on a scientific argument, suggested by William Pollard, Erwin Schrödinger, Barbour, and others, about the extent to which quantum physics plays a role in genetics, and thus in evolution; a philosophical argument, in agreement with Barbour, that

quantum physics is a sign of indeterminism in nature; and a theological argument, again in agreement with Barbour, that we ought to include special acts of God if we are to realize the full promise of evolutionary theism through both top-down and bottom-up models of God's action.

As Barbour argues, a fresh defense of evolutionary theism is enormously important.[7] Arthur Peacocke makes an important response to Monod's argument that "blind chance" makes theism impossible: instead, God acts through the combination of law and chance which God gave to nature as the Creator. However, this argument leaves open the question of whether God can be said to act in *specific* evolutionary events. Recently, Peacocke addressed this issue by appealing to "top-down" or "whole/part" causality. I wish to explore a second route which in combination with top-down causality should provide an important new understanding of God's action in evolution (see also Russell, forthcoming). I believe that quantum physics, interpreted as a sign of indeterminism in nature, in combination with molecular biology and the evolutionary scenario, provides just what is needed to make intelligible the view that God acts in specific events in time in the evolutionary process and that this action can achieve biological consequences via "bottom-up" causality.[8] Since I would ultimately combine this with top-down causality, I can avoid Barbour's criticism that Pollard only discussed bottom-up causality.

If quantum physics signals ontological indeterminacy, we can conceive of God as *acting* in specific events in nature without violating the laws of nature. According to these laws, nature provides a set of necessary causes, but this set is not sufficient to bring about the actual event. If that is true, if science claims that there is no complete set of natural causes for a quantum event, then we can argue that the addition of divine causality brings these events to completion without violating these laws or without being equivalent to a natural or secondary cause. In short, quantum events occur in part because of God's special providence, in part because of natural causality. If God acts at the level of the DNA molecule, contributing to genetic variation, then the combined effect of molecular biology/genetics and natural selection on phenotypically expressed genotype can amplify the effects of divine action to the level of organisms, species, and ecosystems, thus influencing the course of evolution. Diametrically contrary to Monod, evolution is precisely what is needed for divine action, hidden in the undergrowth of quantum chance, to realize the divine intentions for the world.

This claim in turn raises a number of issues to which I respond briefly in the form of six caveats (please see Notes)[9] and several

avenues for further reflection. One can ask whether (1) what we take as quantum chance is merely hidden divine action (no genuine novelty in nature, though apparent novelty to the eyes of science), or (2) what we take as quantum chance involves both divine action and genuine novelty in combination, so that we really have three independent principles of causation: divine action, the causal past, and genuine novelty at the quantum level. The latter would tend more toward a process metaphysics such as Barbour endorses. Finally, a systematic way to integrate top-down and bottom-up causality also must be found for this approach to work. I hope to study these options in future research on theistic evolution.

NOTES

1. He finds support here from the later writings of Bohr and Heisenberg. The latter drew on the Aristotelian category of *potentia* and understood the observer as "forcing one of the many existing potentialities to be actualized." Such a view is strikingly different from the objective determinism of Newtonian physics.

2. The former are supported by Paul Davies and John Polkinghorne, the latter by John Bell and David Bohm. I would agree that Bohm's views, especially if they involve instantaneous connections, are problematic, though I do not think Bohm necessarily interpreted them as violating special relativity. Bell's usual point, as I see it, was to challenge realism by pointing to its failure to interpret quantum correlations and to lay down an obstacle to be faced by any future theory that might replace quantum physics.

3. Again, special relativity admits either an eventlike or a world-line interpretation. The former may seem more promising for technical reasons and it does support a challenge to substantialist thinking, but neither provides a basis for time's arrow.

4. See the challenge to John Polkinghorne, who defends a "flowing time" perspective, by Chris Isham, who defends a "block universe" view, in Isham and Polkinghorne 1993.

5. A curious twist to this story is the following: Gilkey never really argued to minimize the theological importance of $t = 0$ or to dismiss $t = 0$ as secondary to the "real" theological meaning of the doctrine of creation. Instead, Gilkey saw the issue of $t = 0$ as critically important, since it forces us to confront a *foundational* problem which governs and characterizes *every* major doctrine in Christian theology: the dialectic between "the world of fact and experience" and "the transcendent power and love of God" (Gilkey 1959, 315-16). Acknowledging its importance, but unable to introduce empirical language into theology, Gilkey sought to resolve the problem by proposing we view religious language about historical/empirical origins and other empirical facts as myth (Gilkey 1959, 316 ff.). Hence, although I disagree with Gilkey's resolution of the problem, we owe him a great deal for his lucid insistence on its importance. If Gilkey is correct, the epistemological problems surrounding $t = 0$ are well worth *our* pursuing because they are *inherent* to the theological agenda as such, if only we can find a way to revisit them.

6. Barbour writes: "I do not think that major theological issues are at stake [in the case of $t = 0$]. . . . If a single, unique Big Bang continues to be the most convincing scientific theory, the theist can indeed see it as an instant of divine origination. . . . [Still] I agree with the neo-orthodox authors who say that it is the sheer *existence* of the universe that is the datum of theology, and that the details of scientific cosmology are irrelevant here. [Creation *ex nihilo*] is an ontological and not a historical assertion" (Barbour 1990, 129, 144).

7. According to D.J. Bartholomew, Jacques Monod's argument that "blind chance" makes theism impossible constitutes a "devastating attack on belief in a purposeful God. . . . [This argument] is the most penetrating and damaging that has been launched

in the name of science. . . . If true, then Monod's claim would be sufficient to demolish Christianity and most of the other higher religions" (Bartholomew 1984, 16, 2).

8. This proposal takes us beyond classical chance: epistemic ignorance of underlying causal mechanisms. Classical chance pervades evolutionary theory down to the level of molecular biology, and it is the kind of chance Peacocke presupposes in his understanding of God's action in nonlinear, nonequilibrium thermodynamics and in evolution. In my opinion it is hard to see how chance leads to indeterminism in nature and thus to the possibility of divine—or human—agency, unless one appeals instead to quantum physics. Moreover, before evolution had produced "wholes" (i.e., moral free agents), which could act in a "top-down" (i.e., mind/brain) way, it is hard to see how such a mode of causality could be a model for God's acting through evolution to produce such "wholes." Thus, we must turn to quantum physics. Here I presuppose an ontological interpretation of quantum chance as a sign of real indeterminism in nature. Granted this interpretation may prove wrong, but for now I propose we accept it, as Barbour urges us to.

9. *Six Caveats.*

1. This is not an explanation of how God acts, not an argument that God acts, but only a clue as to one possible domain in which that action may have an effect on nature.

2. It is not an interventionist argument, since it relies on what we know from science—namely, that quantum chance points to ontological indeterminism—and since it presupposes that God is always active ubiquitously in nature.

3. It avoids predestination, one of Barbour's main concerns here, since the overwhelming majority of quantum events in which God acts merely result in producing the ordinary classical world and with it the usual presence of law and chance, novelty, and free will. It is only occasionally that God might act to achieve a specific effect *in* that world.

4. It can allow for purpose without foreknowledge if one starts with the premise that God knows every event in its present mode of actuality via the divine eternity. I find Trinitarian conceptions of the relation between temporality and eternity particularly promising here. See the writings of Karl Barth, Karl Rahner, Jürgen Moltmann, Catherine M. LaCugna, Wolfhart Pannenberg, Elizabeth Johnson, and Ted Peters.

5. It calls for renewed attention to the problem of theodicy. The best approach probably lies in a deeper understanding of redemptive suffering and nature as cruciform.

6. Finally, the thesis depends on showing the importance of quantum events to genetic variation. This leads to the importance of the ongoing results of the Human Genome Project, particularly as they contribute eventually to our knowledge about how extensive monogenetic effects are in phenotypic expression compared with polygenetic mutations.

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