EVOLUTION: JOURNEY OR RANDOM WALK?

by Terence L. Nichols

Abstract. Though early ideas of evolution saw it as progressive, most modern theories see it as a random walk. The theories of Richard Dawkins, Stephen Jay Gould, Edward O. Wilson, Stuart Kauffman, Steven Rose, and Robert Wesson are surveyed, showing their agreement on the fact of evolution but not on the mechanism. Evolution is an incomplete theory. Any theology should therefore be based only on its broadest features. Generally, evolution is the development of complex forms from simple ancestors. Within a Christian context, it can be seen as a journey toward the unification of all things in Christ, the ultimate complexity.

Keywords: complexity; context; evolution; mechanism of evolution; progress; Spirit.

In his book *From Monad to Man*, philosopher of biology Michael Ruse explores the history of the idea of progress and its relation with evolutionary thought. His claim is simple: "The idea of evolution is the child of the hope of progress. Like the parent, it too incorporated the hope of upward climb" (Ruse 1996, 72).

Early ideas of evolutionary progress, for example those of Jean Baptiste de Lamarck, saw evolutionary progress as a kind of straight-line development in time from the most simple to the most highly organized and perfect. Evolution involved an upward climb, "from monad to man." Similar notions can be found in the work of Charles Darwin's grandfather, Erasmus Darwin, who thought evolution moved from simplicity to complexity and culminated in humanity. This progressivism is most pronounced in the work of Herbert Spencer, for whom evolution and progress were

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virtually synonymous: "It is in the greater complexity of the co-ordination—that is, in the greater number and variety of co-ordinated actions—that every advance in the scale of being essentially consists" (Ruse 1996, 188).

What was the agent for evolutionary progress? For Lamarck and Spencer, it was not God or Providence but a kind of upward striving in nature itself, the fruits of which were passed on to posterity by a Lamarckian inheritance of acquired characteristics (Ruse 1996, 190).

A variant of these ideas is found among the Germans, who, drawing from Hegel, saw progress as essentially a manifestation of the Spirit, which then found expression in the world of natural forms. Ruse notes that "Germanic Progress is an ascent of the Spirit towards self-realization" (1996, 70). Crucial to German evolutionary thought was the idea that the development of the individual is paralleled in evolutionary development. "In the embryological development of the individual, one sees a kind of internally driven momentum towards a predetermined mature state" (1996, 70). This gave to evolution a kind of directedness, which culminated in humanity.

The idea of evolutionary progress is still found in the writings of Charles Darwin, who also saw humanity (and even Victorian humanity) as the culmination of evolution. But the formative agent for Darwin was natural selection rather than any internal natural tendency to realization (Ruse 1996, 136–77).

Such an idea of progress has been mostly dismissed, however, in modern evolutionary thought, at least in the scientific writings of professional biologists (though Ruse still finds it prominent in museum displays). What seems to have taken its place is the idea that evolution is a kind of random walk, driven largely by chance, tending in no direction at all. The words of Nobel laureate biochemist Jacques Monod are well known: "Pure chance, absolutely free but blind, [is] at the very root of the stupendous edifice of evolution" (Monod 1972, 112). Francis Crick concurs: "Chance is the only source of true novelty" (Crick 1981, 58). The American paleontologist George G. Simpson holds that "evolution is not really orthogenetic. Trends do not keep on indefinitely but level off, change direction, or even become reversed. Valid predictions cannot be made by extrapolating a past trend into the future" (Simpson 1964, 272). For Richard Dawkins, "the only watchmaker in nature is the blind forces of physics" (Dawkins 1987, 5). Ernst Mayr argues that "the one thing about which modern authors are unanimous is that adaption is not teleological" (Mayr 1983, 324–34). Stephen Jay Gould likens the course of evolution not to a tree but to a branching bush, which opportunistically grows into whatever space or niche is provided for it by the shifting environment. Human beings themselves are the products of chance, not design or direction. Gould writes, "the origin of *Homo sapiens*, as a tiny twig on an improbable branch of a contin-

gent limb of a fortunate tree, lies well below the boundary [of law and contingency]. In Darwin's scheme, we are a detail, not a purpose or embodiment of the whole—'with the details, whether good or bad, left to the workings of what we call chance'" (Gould 1989, 291).

However, this picture must be qualified somewhat. While the idea of any absolute progress, that is, progress toward a goal, such as humanity, is rare in contemporary evolutionary thinking, there is a kind of relative progress implicit in the very idea of adaptation: an organism that is well adapted to its environment is relatively more evolved, or "progressed," we might say, than one that is not. This notion of progress is defended by Richard Dawkins, among others. "Progress," he writes, is "a tendency for lineages to improve cumulatively their adaptive fit to their particular way of life, by increasing the numbers of features which combine together in adaptive complexes" (Dawkins 1997, 1016). But this merely means progress toward "fit," or adaptation; or, to use a favorite metaphor of biologists, progress up the fitness peak in an adaptive landscape. This is progress resulting from natural selection, which is in evolutionary theory an antichance factor. But natural selection simply molds populations to their environment by winnowing out the less fit. It does not connote that evolution is teleological or orthogenetic. Indeed, it might be argued that behind natural selection stands chance, for if the environment changes, the selection pressures change. But changes to the environment seem to be due to chance, as when an asteroid collided with the Yucatán peninsula some 65 million years ago and created drastic climatic changes that resulted in the extinction of the dinosaurs and the subsequent proliferation of the mammals. (By *chance* here I mean the intersection of two unrelated causal chains, which results in events that are apparently unforeseeable and purposeless.)

There are some exceptions, however, one of the most prominent being sociobiologist Edward O. Wilson. Ruse quotes Wilson as saying, "The transition from prokaryote to eukaryote is evolutionary progress. It represents evolutionary progress in the sense that it built upon a preexisting order and achieved a conspicuously higher degree of sustained complexity. It permitted the opening . . . of a whole array of new ecological niches . . . it represented important advances in sustained complexity, and expanded life as a whole into modes of existence and parts of the environment that had not been occupied before" (Ruse 1996, 512–13). But this notion of progress—from simple organisms to sustained complexity, from a few organisms to extensive biodiversity—is not orthogenetic, in the sense that evolution is directed toward some preestablished goal, perhaps as a result of Providence. Wilson, an atheist, would certainly deny this. He would probably argue, however, that inherent in the very mechanism of evolution is the possibility of progress toward greater complexity and diversity.

There are, then, some vestiges of the idea of progress still present among evolutionists. Some, like Dawkins, argue for a relativistic notion of progress

as adaptive fit. Others, like Wilson, argue for a kind of absolute progress, from simplicity to complexity, homogeneity to biodiversity. But, as Ruse notes near the end of his book, most professional evolutionists do not bother with the idea of progress anymore; it just does not figure in their scientific work. "If you are a professional evolutionist, working on micro-problems, then there is neither need nor temptation to bother yourself with questions of progress, and most likely, *qua* professional biologist, you will not" (Ruse 1996, 525).

Differing Theories of Evolution

It is important to affirm that there is a consensus among practicing biologists as to the fact of biological evolution, by which I mean descent with modification from a common ancestor or ancestors. Furthermore, the development of the universe from the Big Bang to the present state can also be seen as a cosmic evolution, from a very simple homogenous state to a complex, diverse state—like Wilson's view of biological evolution. But there is some disagreement among biologists as to the mechanism of evolution. Are random mutation and natural selection the dominant agents of evolution, as Dawkins thinks, or only two factors among many, as others, like Gould, maintain? At what level does selection operate—at the level of the gene (Dawkins again), the individual, the group, or at all these levels simultaneously (as Gould thinks [1997, 1023])? Are there perhaps factors causing evolution that are still largely unexplored, such as the process of self-organization in systems, as Stuart Kauffman proposes, or effects from chaos theory, as Robert Wesson proposes? It is important to raise these questions, because if we just read one author—Dawkins, for instance—we will get the idea that evolutionists agree on the mechanisms of evolution, and this is not the case. There is agreement on the fact of evolution, broadly defined, but there are a number of ideas concerning the mechanism and the paths of evolution. This means that there is not one theory of evolution but many theories. An obvious inference from this is that we do not yet possess a finished theory of evolution; it is still in the making. Indeed, David Depew and Bruce Weber's massive book on this subject, *Darwinism Evolving* (Depew and Weber 1995), makes just this point. This has serious implications for any attempt to develop a theology of evolution, a point to which I shall return. But first let me briefly sketch some of the different theories of evolution that are currently competing for fitness in the academic environment.

I begin with the most triumphalist account, that of Richard Dawkins, whose view of evolution has been laid out in a series of popular books: *The Selfish Gene* (1976), *The Blind Watchmaker* (1987), *Climbing Mount Improbable* (1996), *River out of Eden* (1995), and others. Dawkins's version of evolution is based squarely on the agency of natural selection:

> Natural selection, the blind, unconscious, automatic process which Darwin discovered, and which we now know is the explanation for the existence and apparently purposeful form of life, has no purpose in mind. It has no mind and no mind's eye. It does not plan for the future. It has no vision, no foresight, no sight at all. If it can be said to play the role of "watchmaker" in nature, it is the *blind* watchmaker. (Dawkins 1987, 5)

Selection for Dawkins is at the level of the gene, and his vision is resolutely reductionistic: "a central truth about life on earth . . . is that living organisms exist for the benefit of DNA rather than the other way around" (1987, 127). Human beings are no more than machines created by genes: "We are survival machines, robot vehicles blindly programmed to preserve the selfish molecules known as genes" (Dawkins 1976, v). Evolution itself results from the accumulation of millions of tiny changes (themselves due to random mutation), which are sorted and directed toward adaptive complexity by the blind activity of natural selection. Thus, to take one of his (and Darwin's) favorite examples, the complex eye is the result of thousands of tiny changes, from simple light-sensitive spots, to pinhole-camera-type eyes, to lensed eyes (Dawkins 1987, 84–86).

On the other side of the Atlantic is Dawkins's rival, the American paleontologist Stephen Jay Gould. Gould is famous as one of the developers, with Niles Eldredge, of the theory of punctuated equilibrium. This view of evolution emphasizes that the fossil record reveals not so much gradual development, as would be expected from Dawkins's view of evolution, as long periods of stasis (equilibrium) punctuated by sudden extinctions, or the apparently sudden emergence (in geologic time) of new species (Gould and Eldredge 1977). As Dawkins has frequently noted, this may merely mean that the formative period of a new species is compressed into relatively short geological periods (Dawkins 1987, 229–52). But Gould has for a long time argued against Dawkins on several points. First, he maintains that natural selection acts at many different levels of "Darwinian individuality (from genes to organisms to demes to species to clades)" (Gould 1997, 1023) and not just at one level, the gene. Second, with his colleague Richard Lewontin and the British biologist Steven Rose, he insists that organisms shape their own environments and are consequently not simply passively shaped by natural selection (Gould 1997, 1022). Natural selection, Gould writes, is "a necessary, but by no means sufficient, principle for explaining the full history of life" (Gould 1997, 1022). Third, much more than Dawkins, he opts for the role of chance in evolution. In *Wonderful Life* (1989) he argues that massive extinctions have played a major role in shaping the direction of evolution and that the survival of species through these events is truly random, not the result of natural selection. "The history of life is a story of massive removal followed by differentiation within a few surviving stocks, not the conventional tale of steadily increasing excellence, complexity, and diversity" (Gould 1989, 25). Thus,

if the tape of life were played back again, it would in all probability reveal a vastly different scenario. Gould is hostile to any notion of progress in evolution. Advances toward complexity, he says, can be balanced by regression from complexity, as in the case of parasites; progress is in fact a statistical illusion, fostered by humanity's anthropocentric hopes (Gould 1996).

A number of other biologists also have challenged the centrality of natural selection. Prominent among these is Stuart Kauffman, a member of the Santa Fe Institute. Kauffman's core idea is that, besides random mutation and natural selection, there is another source of order in biological processes: self-organization. Complex systems, from computer-modeled networks to biological systems, exhibit a surprising degree of spontaneously generated, emergent order (simple examples of this, in physics, are the hexagonal structure of snowflakes and the cone shape of sand piles). Kauffman holds that self-organizing processes are the origin of life itself and the origin of much of the order in living systems generally. He explains:

> In this book I propose that much of the order in organisms may not be the result of selection at all, but of the spontaneous order of self-organized systems. . . . The order of organisms is natural, not merely the unexpected triumph of natural selection. For example, I shall later give strong grounds to think that the homeostatic stability of cells, the number of cell types in an organism compared with the number of its genes, and other features are not chance results of Darwinian selection but part of the order for free afforded by the self-organization in genomic regulatory networks. If this idea is true, then we must rethink evolutionary theory, for the sources of order in the biosphere will now include both selection and self-organization. (Kauffman 1995, 25)

Kauffman's work parallels that of a number of biologists, including Brian Goodwin (1994), Mae Won Ho (Ho and Saunders 1984), and Rose (1998), all connected with the Open University in Britain. The focus of their biology is on the centrality of the whole organism and its processes of development rather than on the gene. Depew and Weber have this to say about the effects of this new thinking in developmental biology, which is challenging the hegemony of Darwinian orthodoxy:

> By contrast to Darwinism's stress on random variation and selection by external, environmental forces, an older and surprisingly persistent developmentalist tradition has consistently maintained that the evolution of kinds (phylogeny) should be viewed as an inner driven process like the unfolding of an embryo (ontogeny). . . . The developmentalist tradition displaced Darwinism in the later nineteenth century, but was in turn marginalized by it for most of the twentieth century. . . . Emboldened by the resources of nonlinear dynamics for analyzing self-organizing phenomena at various levels of the biological hierarchy, latter day developmentalists [such as Goodwin, Mae Won Ho, et al.] have been asserting of late that natural selection, and so Darwinism, will not survive the transition from the "sciences of simplicity" to the "sciences of complexity." (Depew and Weber 1995, 18)

Gould has been sympathetic to these developments. He writes, "The constraints of inherited form and developmental pathways may channel . . .

changes so that even though selection induces motion down a permitted path, the channel itself represents the primary determinant of evolutionary direction" (1982, 383).

British biologist Rose also emphasizes the centrality of organisms and their "lifelines" and is an acerbic critic of Dawkins and of genetic reductionism in general. Rose, a Marxist, argues passionately for "making biology whole again" (Rose 1997, 302). The kernel of this program is the idea that within the world different levels of organization emerge, which have to be explained by different methods. "So at each level different organizing relations appear, and different types of description and explanation are required. Hence each level appears as a holon—integrating levels below it, but merely a subset of the levels above. In this sense, levels are fundamentally irreducible; ecology cannot be reduced to genetics, nor biochemistry to chemistry" (Rose 1997, 304). Living things are conditioned by their components but also by their environments and contexts and unique histories. Furthermore, organisms affect their environment even as the environment affects them. The future of evolution, then, is radically unpredictable. Humans are the more or less accidental product of evolutionary forces but are nevertheless free to some extent to construct their own future (1997, 309).

Robert Wesson argues that conventional neo-Darwinism is too simple and too mechanistic an explanation for evolution—it is the parallel of Newtonian physics in biology. Recent scientific advances, especially in chaos theory and theories of self-organization, are necessary to get a better understanding of evolution. Evolution is the story of the development of complex systems, exactly the kind of systems described by chaos and complexity theory. Wesson sees the emergence of stable genomes and stable biological patterns as examples of what are called in complexity theory "attractors." He writes, "Any self-reinforcing pattern, or a self-ordering part within the self-ordering whole, such as the brain . . . may be considered an attractor. Any taxonomic group, as far as it represents a set of organisms that belong together, represents an attractor at its level" (Wesson 1991, 146). Complex dynamic systems, stabilized by the presence of attractors, resist change (this is the origin of stasis in species), but when they do change, they change not gradually, but suddenly, as they shift to another stable pattern. This might be the origin of speciation. Wesson concludes that "Evolution is the result of at least four major factors—environment, selection, random-chaotic development, and inner direction—and one might no more expect to find any law to govern it than to find a law of the mind" (1991, 291). Wesson does think that evolution progresses in the direction of complexity and biodiversity and that biological evolution gives way to cultural evolution in human societies.

Now admittedly the ideas of Kauffman, Goodwin, Ho, Rose, Depew and Weber, and Wesson (most of whom are practicing biologists) are outside

the mainstream of contemporary neo-Darwinian orthodoxy, which typically explains evolution by random mutation, natural selection, genetic drift, and chance factors (a sudden change in the environment, for example). Indeed, most biologists, concerned as they are with microproblems (see the articles in any issue of the journal *Evolution),* have probably not read these authors. But even a slight knowledge of the history of science teaches us that minority ideas sometimes prove to be the key to scientific advance. (A striking example is the theory of continental drift, which was ridiculed for decades yet is now one of the foundational theories in modern geology.)

The point of this brief survey is to demonstrate that, while there is consensus on the fact of evolution, there is disagreement on the mechanism of evolution—what drives it, or on whether or not, or in what sense, it might be progressive. Almost no practicing biologist, as far as I know, would argue that evolution has a preordained target (for example, humanity). But some, like Dawkins or Wilson, argue for a kind of progress from simplicity to complexity, while others, like Gould, argue against any progress at all. The resurgence of developmental thought based on self-organization and nonlinear dynamics may forecast a major change in evolutionary theory.

From this I draw a provisional conclusion: We do not now have a finished theory of evolution; it is still incomplete. Perhaps, as Depew and Weber suggest, it is still evolving. This means that any *theology* of evolution must necessarily be extremely tentative, because the shape of evolutionary theory one hundred years from now may be quite different from what it is now.

There is good reason to be tentative. The history of science over the last few centuries shows clearly that scientific theories are provisional and subject to drastic reformulation even after having commanded a consensus for decades, or even centuries (as in the case of Newton's theory). An obvious and well-known example of this is the fate of the theory concerning the ether. The existence of the ether as a necessary medium to transmit light waves was unquestioned by physicists for most of the nineteenth century (Jaki 1966, 79–86). Indeed, James Clerk Maxwell, one of the giants in the history of physics, wrote the article on the ether for the ninth edition of the *Encyclopaedia Britannica* (1878), in which he calculated the coefficient of rigidity and density of the ether to two decimal places. He concluded the article with these words:

> Whatever difficulties we may have of forming a consistent idea of the constitution of the ether, there can be no doubt that the interplanetary and interstellar spaces are not empty, but are occupied by a material substance of body which is certainly the largest, and probably the most uniform body of which we have any knowledge. (Maxwell 1878, 572)

This was written about 124 years ago. And yet today, the theory of the ether has only historical interest. It has gone the way of the phlogiston theory and the geocentric universe.

Thus, it is risky to speculate on what the theory of evolution might look like 124 years from now, especially with potentially revolutionary developments on the horizon. Nonetheless, I will hazard a tentative theology of evolution.

A Theology of Evolution

One of the features of evolution that seems the most certain is that, over the long history of the universe, there has been a development from extremely simple, homogenous systems to complex systems in which diverse elements are unified into a functioning system. (I define a complex system as one in which many diverse parts and kinds of parts are interrelated into a functioning whole.) This can be seen in the evolution of organisms and humanity but is even more apparent in the evolution of the cosmos from the initial instant of the Big Bang to the present. Stars and galaxies are not enormously complex objects, but by any measure of complexity they are more complex than the pure energy/matter that constituted the universe just after the Big Bang.

Can this evolution toward complex systems be understood as providentially ordered by God?

Within a context of philosophical naturalism—that is, the worldview that only nature, and nothing greater than or other than nature, exists—I think it likely that evolution will be seen as a random walk, driven by chance and necessity, and human life as the fortuitous by-product of a blind process. There are at least two reasons for this.

First, natural science from the time of Galileo has rejected any final causes in nature. Final causes are neither quantifiable nor measurable and so found no place in the "new science" of Galileo and Newton. Indeed, Monod declares that it is precisely the rejection of final cause that is constitutive of modern science (Monod 1972, 21), which concentrates instead on efficient and material causes. The method of modern natural science, then, simply could not disclose final causes, even if they were present. And this methodological limitation has become a metaphysical outlook: Final causes don't exist, because science cannot perceive them, and we know that what science tells us is true.

Second, as Wolfhart Pannenberg reminds us in numerous writings, we cannot really know the whole of a process, including its aim or purpose (if there is any), until the process is complete. This is obvious in a journey; if a person sets out in an automobile from San Francisco, it would be foolish to try to guess the goal of her journey before she arrived at her destination. Similarly, we cannot foretell the end of a book by reading only its first half. So even in principle it is not possible to articulate the goal or purpose of evolution until the end of the evolutionary process.

Now Christian theology claims to know what that end is, but it is an end that can be known only through revelation: namely, the reconciliation of humanity and the cosmos with their Creator. The author of Ephesians writes, "He [God] has made known to us the mystery of his will, according to his good pleasure that he set forth in Christ, as a plan for the fullness of time, to gather up all things in him, things in heaven and things on earth" (Ephesians 1:9–10 NRSV). This will be the kingdom of God, which was the principal object of Jesus' preaching and of his mission.

Furthermore, Christianity claims that the author of the whole universe and all life is God. This is clear in the first chapters of Genesis and also in the first chapter of the Gospel of John, which says, "All things came into being through him" (i.e., the Logos) (NRSV). Pannenberg argues persuasively that the Logos, the second person of the Trinity, is the ultimate principle of distinction and hence the ultimate origin of distinct, created forms in the universe (Pannenberg 1994, 109–15).

Thus, Christianity sees reality as structured according to a journey: the cosmos and its creatures come from God in creation and are called back to fellowship with God in the eschaton, the end times. We can see this structure in the Gospel of John, in which the Logos descends into the world in the incarnation and returns to God in the resurrection. We can see it also in the *Summa Theologiae* of Thomas Aquinas (1947), the first part of which treats of the origins of creatures from God and the last part of their return to God.

Indeed, traditional Christianity might even be said to have a kind of evolutionary structure, despite all the stereotypes of its being a static religion. The kingdom of God develops from a small seed (as in the parable of the mustard seed) to a great tree, and from a few disciples (a "founder population," to use Ernst Mayr's phrase [1998, 173]) to a movement spread across the earth. Furthermore, many of Jesus' sayings and parables emphasize that there is a selection process involved: "For many are called, but few are chosen" (Matthew 22:14 NRSV).

Thus, I think it likely that, when viewed within the context of a Christian worldview, evolution is likely to be perceived as a kind of journey, which has, after all, a goal. We can see in evolution a movement from simple systems to complex systems, both at the cosmic level and at the level of organic evolution, and we can also see this in the Christian view of history. For the end and culmination of history is, according to Christianity, the gathering of all the blessed into fellowship with God, through Christ and the Holy Spirit. And that is not all. Paul prophesies that the whole cosmos as well will "be set free from its bondage to decay and obtain the glorious freedom of the children of God" (Romans 8:21 NRSV). Certainly this would be the most complex system of all, containing maximal diversity but also maximal unity.

But to say that evolution, perceived through the eyes of Christian theol-

ogy, is a journey is not to say that the sole aim of the evolutionary process is to produce human beings, or even intelligent life. Genesis 1 declares that all of creation is good in its own right, quite apart from the goodness of humanity. This is the point of the refrain, repeated after each day of creation, "And God saw that it was good." Thomas Aquinas also argues that God created so many and diverse kinds of creatures because only the whole panoply of creation would adequately express God's goodness. His reasoning is worth an extended quotation:

> For He [God] brought things into being in order that His goodness might be communicated to creatures and be represented by them; and because His goodness could not be adequately represented by one creature alone, He produced many and diverse creatures, that what was wanting to one in the representation of the divine goodness might be supplied by another. For goodness, which in God is simple and uniform, in creatures is manifold and divided; and hence the whole universe together participates the divine goodness more perfectly and represents it better than any single creature whatever. (Aquinas 1947, 1:47,1)

This point is also brought home by the doctrine of the Resurrection, especially if that involves the cosmos, as Paul and the book of Revelation proclaim. As John Polkinghorne has written (1995, 105) and as traditional Christian doctrine affirms, in the eschaton, nothing that is good will be lost.

But although evolution can be seen as a kind of journey, culminating in the reconciliation of all things in Christ, it is a journey fraught with tragedy. In nature, the price of life is the death of another, both to make room for new life and to provide resources for new life. This is true not only for individuals but for species; most species in the course of evolution have become extinct, and their death opened econiches that were then filled by new, creative forms of life. There is no better example of this than the extinction of the dinosaurs, which had flourished for more than a hundred million years; their extinction opened the way for the flourishing of the mammals, by the process biologists call adaptive radiation.

More than most religions, Christianity has resources to make sense of this paradoxical evolutionary history. For theologically, the tragedy, death, and subsequent creative transcendence of evolutionary history is the same pattern that is manifested in the life and death of Jesus: cross, death, and resurrection. The cross and death seem to be the necessary prelude to the transcendence of the resurrection, and it is a truism in Christian spirituality that one cannot ascend spiritually without first undergoing a dying to self. So in organic evolution, I see a pattern of cross, death, and subsequent transcendence.

Now, if creation comes from God, how does God act in the process of evolution?

First, of course, Christian theology has traditionally affirmed that God created the universe "from nothing." This is not obvious in Genesis 1,

though it might be argued that the waters of chaos over which the Spirit broods in Genesis 1:2 are a poetic symbol for "nothing," because chaos is the absence of all form, and the absence of all form would be precisely nothing. But we cannot conclude on scientific grounds that the Big Bang means that the universe was created from nothing. After all, there might have been a previous universe, which imploded, or a previous condition, all trace of which has been lost. But at least we can say that the scientific scenario of the Big Bang is consistent with the belief that the universe was created from nothing. As Robert Russell has pointed out, if we asked what a creation from nothing would look like scientifically, the answer is: like the Big Bang.

But God's creative work does not stop with the initial creation. To say that would be to adopt a modern form of Deism, in which God created the world, like a watch, wound it up, and let it run on its own. The biblical view is different: God's Spirit remains active, as a creative principle, in creation. As the psalmist declares, "When you send forth your spirit, they are created, and you renew the face of the ground" (Psalm 104:30 NRSV).

How then might the Spirit act in evolution? I agree with Wesson that evolution is not the result of one cause but of many acting in concert. Among those causes I would include the Spirit. (Wesson probably would disagree with this.) Some, like Robert Russell, Nancey Murphy, and others, have argued that God or the Spirit acts at the level of quantum indeterminacy, determining specific mutations and so steering the course of evolution. Arthur Peacocke, who rejects this idea, thinks that God acts through "whole-part constraint," in which the whole constrains the action of the part, without violating any natural laws (Peacocke 1998, 369). In this admittedly very indirect way, God can act in nature and evolution.

I propose another idea, similar in some ways to Peacocke's idea but also different. I call it "contextual causality"—the idea that the context of things or events functions as a kind of cause that complements the reductionist causality that is pervasive in the sciences. Let us consider the case of human artifacts. Every artifact is designed to function within a quite specific context. An ax, for example, presumes a context that includes intelligent, tool-using, two-handed beings, with metallurgy and woodworking skills, and an environment containing wood of a certain hardness. Axes come in many types: single-bitted, double-bitted, large, medium, and small. But their form fits within a certain range of shapes and sizes, determined by the context. We do not find axes that weigh a hundred pounds, have ten-foot handles, or are made of rubber. Thus, I think we can say that in a way the context shapes, within limits and through the agency of human design, the form of the ax. Or consider a modern automobile. It is designed for a context that includes paved roads, gasoline, metallurgy, plastic, rubber, electricity, two-handed drivers of a certain size, intelligence, and visual ability, a planet that has oxygen and a specific gravitational pull, and so on.

There is of course a wide variety of cars, trucks, and buses, but they all exist within limits set by the context. Imagine a modern automobile in a very different context, say the moon or the Roman Empire, and you can see the point. Indeed, it is a routine technique in archaeology to reconstruct the context from an excavated tool or object. So, we can maintain that the context influences the form, within limits, of the artifact.

But context also shapes natural creatures: this is the whole point of natural selection. The environment winnows out the unfit from the fit and so shapes the structure of a population. The expression of genes is also determined by context (which includes the whole genome), a point made forcefully by Rose (1997, 139), Goodwin, and others. Goodwin notes that what determines the sex of Mississippi alligators is the temperature at which their eggs incubate: between 26^0 and 30^0C, all the eggs develop into females; between 34^0 and 36^0, all become male, and between 31^0 and 33^0, they can develop into either sex (Goodwin 1994, 40).

Even in the case of the cosmos itself, the values of four basic forces, and physical constants, determine within a certain range what kind of development might take place. Work connected with the anthropic principle has shown that if the basic forces and physical constants of the universe were even slightly different from what they are, the result would be a universe that probably could not support life (Barrow and Tipler 1988; Leslie 1989, 2–6).

Now the kind of causality being exercised here is similar to what Aristotle and Aquinas called formal causality and what moderns would call the input of information. It is the form, structure, or information content that is influenced by the context. In the case of artifacts, this is mediated through the agency of human design and work. In the case of nature, it is mediated through natural selection or the values and balance of the fundamental forces and physical constants. If physical contexts thus influence the form of creatures, I argue that the ultimate context of the universe can also influence the form of creatures.

What is the ultimate context of the universe? For many in the physical sciences, it is the universe itself. Here again, though, I would argue that there is much that we do not know about the universe, even about the nature of matter. If the physicists engaged in string theory are right, matter is composed of strings that vibrate in nine spatial dimensions, only three of which are directly observable by us (Greene 1999). Thus, even the roots of matter may be only partially knowable.

At any rate, from the perspective of Christian theology the ultimate context of the universe is God, who transcends the universe but is also present to it at every point and at every moment, and who holds it in being.

This idea seems to relate closely with Pannenberg's idea of the Spirit as a field—as he puts it, the "field of force of the divine future from which

events proceed contingently" (Pannenberg 1994, 110). I take it that the Spirit is not a field that could be measured by a physicist but that it nonetheless is real and makes its activity felt in the present. Like other forms of contextual causality, which do not determine specific events and specific forms but constrain form within a set of limits, the Spirit might act accordingly. I would see its role in guiding evolution as the input of information and so catalyzing one form of development rather than another. I do not see it as specifying evolution in all the details; a large role is left to stochastic processes, that is, to chance. We can see this in any number of physical processes. For example, the laws of physics and chemistry determine the hexagonal form of snowflakes, yet no two are alike, and the precise pattern of each is apparently determined by contingent circumstances. Again, genes determine that we have ten fingers, yet the patterns of the whorls on the fingers—the fingerprints—are not determined by the genes but are partly the result of chance.

John Polkinghorne has shown just how sensitive physical processes can be to context. He notes that in 10^{-10} seconds, a molecule of air will on average have fifty collisions with neighboring molecules. Now, he asks, let's say we want to predict the direction of a given molecule after fifty collisions: how accurately will we have to know the initial circumstances of it and its neighboring molecules to make this prediction? The answer is staggering: to make an accurate prediction, we would have to take into account the gravitational force of a single electron on the other side of the universe (Polkinghorne 1995, 79–80)! This is because, as every pool player knows, a tiny discrepancy in the angle of incidence in the first collision increases exponentially with every successive collision. This is a measure of how sensitive even very simple physical systems are to their context. Clearly, we cannot ever know the context with this degree of accuracy. Practically speaking, then, even deterministic systems, like the successive collisions of molecules of air, are intrinsically unpredictable, even though the equations governing them are deterministic. This is one of the conclusions of chaos theory. Polkinghorne concludes from this, and I agree, that the processes of the universe are open, not closed, and that God, or the field of the Spirit, can act within them without violating physical laws (Polkinghorne 1995, 76–90).

As an example, let us consider a hypothetical instance of speciation. Most biologists now think that new species develop from so-called founder populations, that is, a small fraction of a larger population which has become isolated from the parent population, perhaps because of a geographical barrier, like a stream, or because of migration or some other factor. This founder population may have a gene reservoir that differs from that of the parent population. Furthermore, environmental pressures might push the small population in a direction different from its parent. Add to this the possibility of chaotic dynamics—that a small population may evolve rap-

idly in the direction of a different adaptation, and hence of a new species. Now, some of the influences catalyzing this change may be quite small—a change in weather patterns, for example, or a change in the behavior of a few individuals. Such might be the pathways by which the Spirit could influence the progress of evolution.

Thus, I think that God the Spirit, as the ultimate and yet immanent context of the whole universe, can certainly act to influence the course of evolution, not only by acts of intervention but by the constant presence of a field that gently and imperceptibly draws creation toward an ultimate goal of reconciliation with its creator. If the Spirit is the field of the future, and if that future is the reunion of all things with God, this may be one explanation for the universal tendency toward increasing complexity and diversity in the universe.

I have another possible hypothesis for how the Spirit might work in the world. I would argue that there is no absolute disjunction between Spirit and matter. Creation and creatures proceed from the Spirit and have their own independence. One instance of this independence is constant natural laws. But if there were an absolute disjunction between Spirit and matter, then there could be no influence from one to the other, in either direction. God could not influence events in our universe, nor could we influence God, through prayer or any other way. The idea that God is "wholly other" has always seemed to me to be problematic, for if that were true, we could know nothing of God, even that God exists. Nor could God reach us, even through revelation.

There is, then, a continuity in being between God the Spirit and matter. But there is also a discontinuity. We and the physical universe are not little pieces of God—this is the view of pantheism. We are creatures possessing our own degree of autonomy. This is manifested in physical objects obeying the laws of nature and in humans being able to make free choices, including the choice to reject God. I agree with Polkinghorne and others who hold that the gift of love is the gift by God of a degree of freedom and autonomy to creatures.

So, there is continuity and discontinuity. In Catholic thought, one way to speak of this is in the language of participation. We can participate in the grace of the Spirit while yet being distinct from the Spirit. Similarly, I believe, the energy of the cosmos can participate in the creative field of the Spirit while being distinct from the Spirit. If, according to string theory, the roots of matter span more than three spatial dimensions, then even in principle science could not detect all of the influences on matter. Furthermore, recent experiments have revealed the nonlocal interaction of particles at a distance. So far the mechanism by which this takes place is unknown and seems to be beyond what presently can be explained by physics. But recall where physics was a century ago. Perhaps in another century advances in physics will enable us to have a better idea of where

the causal joint between Spirit and matter might lie. If there is a continuity of Spirit and matter, and if the cosmos is not a closed but an open system, then the Spirit should be able to influence matter without violating the integrity of physical laws, though we cannot at present say exactly how.

Thus, it seems to me reasonable, at least from the perspective of Christian theology, to believe that one factor in the course of evolution is the action of the Spirit, which like a field influences events ever so slightly, so as to, over millennia, move evolution toward its goal, which is the return of the cosmos to its Creator. One way for this to happen is for the cosmos to produce intelligent beings who can acknowledge their Creator in love and freedom. As Pierre Teilhard de Chardin saw, humanity is creation become conscious, and human worship is the creation returning its praise to the Creator.

What is the end of this evolutionary journey? I agree with those like Teilhard and Wesson who see evolution as moving from the biological level to the cultural level in the case of humans (and perhaps the higher primates). Furthermore, I would not rule out the possibility that evolutionary processes have produced beings of high intelligence elsewhere in the universe.

But in the Christian vision, the journey of humanity and indeed all of creation back to God is completed only in resurrection. The resurrection of Jesus has traditionally been understood in Christianity as a promise of a more general resurrection, which will include all humanity and, if Paul is right in Romans 8, even the creation itself. This is of course deeply mysterious, because we have no examples of it in our present world. Furthermore, is it even conceivable that biological and cultural evolution could evolve to a kind of spiritual evolution culminating in resurrection? Let me offer a few reflections.

First, and most obvious, the resurrection seems to involve a different kind of materiality from our own. Jesus' body, before his ascension, was palpable to his disciples—clearly physical, then, but also seemingly not constrained by the limitations of space and time (see John 20:26). A Christian notion of the resurrection is not a resuscitation; the resurrected body would not be just like our bodies now but would be, as Paul puts it in 1 Corinthians 15, a spiritual body. There is a continuity with present materiality, but also a discontinuity. The resurrection involves a kind of transcendence for which we have no evidence besides the resurrection of Jesus himself.

The only way this is possible is through the agency of the Spirit. If matter and Spirit are, as I have argued, continuous in some sense, then the kind of transcendence imaged in Jesus' resurrection might be a possibility. The resurrection does not involve a "jump" to nonmateriality, but it does apparently involve a transcendence to another kind of materiality.

But if such a transcendence is possible, I do not see it as a gradual transcendence. Jesus' resurrection was preceded by a terrible death. We have seen that this pattern seems to be part of the story of evolution: cross, death, then transcendence. I would expect the same to be true in the case of the resurrection. As Polkinghorne states, the new creation is consequent upon the death of the old (Polkinghorne 1995, 104–9).

As a Christian, I see the general resurrection as the reconciliation for all humans and all creation with Christ, the incarnate Logos, through whom the creation was formed. This is the vision of the kingdom of God, the object of Jesus' preaching, and the vision of Paul's letters and of the book of Revelation. It would seem to be the ultimate in unified diversity—in other words, in complexity. It is tempting to see in this icon a kind of dynamic attractor, to use the language of chaotic dynamics: a stable pattern that draws the long process of evolution toward a greater harmonic diversity and complexity to its final consummation. I believe this is also consonant with the vision of Pannenberg: that the Spirit draws the process toward a goal that, like any journey, cannot be fully understood except from the perspective of the end.

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