



*Articles*



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# *Epigenetics, Evolution, and Us*

W. Malcolm Byrnes

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We are acting on a geological and biological order of magnitude. We are changing the chemistry of the planet. We are altering the great hydrological cycles. We are weakening the ozone layer that shields us from cosmic rays.... We are upsetting the entire earth system that has, over some billions of years and through an endless sequence of experiments, produced such a magnificent array of living forms.<sup>1</sup>

Ecological theologian Thomas Berry

The last several years have witnessed the sequencing and annotation of the genomes of dozens of organisms, including various microorganisms, a nematode worm, the fruit fly, the malaria mosquito, the laboratory mouse, and of course, humans. One of the benefits of unraveling the genomic sequences of increasing numbers of organisms is that it allows a clearer determination of the evolutionary relationships among Earth's creatures. The comparison of genomes has revealed that the genes that encode enzymes of essential metabolic and communication pathways within cells are amazingly similar across kingdoms, from man to microbes. Other genes, such as those that control the formation of body shapes during embryonic

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<sup>1</sup>T. Berry, *The Dream of the Earth* (San Francisco: Sierra Club Books, 1988), 206.

development, also are highly conserved among animals from fruit fly to human. Among primates, the similarity between genomes is high, with ninety-eight percent of the sequence identical between chimpanzees and humans, for example. One of the insights that arises from these genomic comparisons is how intimately connected we humans are to the multitude of life forms on Earth. These profound interconnections also suggest a primordial common ancestor for all of life on Earth, although a determination of when this mythical creature arose and what it looked like may not be possible.<sup>2</sup>

This essay will move along broad lines from molecular biology to evolutionary biology and ecology to theology. Its objectives will be to: 1) present some recent scientific findings in the emerging field of epigenetics that indicate that it is “the genome in context,” not genes per se, that are important in biological development and evolution; 2) show that this weakens the gene-centric neo-Darwinist explanation of evolution which, in fact, shares a certain preformationist orientation with intelligent design theory; 3) argue that the evidence against a gene-centric view in no way negates Darwin’s central idea of “descent with modification”; 4) argue that an embrace of the evolutionary story, with all of its contingency and apparent lack of

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<sup>2</sup>Molecular phylogenetics is the branch of evolutionary biology that involves the construction of phylogenetic trees based on similarity among nucleotide sequences of genes of organisms; construction of such trees allows one to examine evolutionary relationships among species. One of the genes commonly used for phylogenetic tree construction is the 16S ribosomal RNA (16S rRNA) gene. Recent analysis of sequences of genes other than the 16S rRNA gene—particularly those encoding metabolically functional enzymes—have yielded trees that are different. The main culprit for this disagreement is a process called *horizontal gene transfer* [HGT] that occurred rampantly between prokaryotic microorganisms on the early Earth and, indeed, still occurs today and is responsible for much of the antibiotic resistance that has occurred in recent decades. Sequencing of genomes has aided molecular phylogeneticists by enabling the comparison of multiple gene sequences for the construction of trees, reducing the 16S rRNA bias. Although such comparisons largely confirm the broad branches of the so-called “tree of life,” especially in its upper reaches, the base of life’s tree is a tangled web rather than a smooth trunk. Carl Woese, the molecular biologist at the University of Illinois who pioneered the use of rRNA genes to make phylogenetic trees, recently has suggested that instead of talking about a common ancestor for life, we should talk about a “Darwinian threshold,” a point in evolution after which speciation became possible, but before which speciation was impossible. Woese writes: “The Darwinian threshold truly represents the Origin of Species, in that it represents the origin of speciation as we know it.” C.R. Woese, “On the Evolution of Cells,” *Proceedings of the National Academy of Sciences USA* 99.13 (June 25, 2002): 8744. Then, referring to Darwin’s classical Doctrine of Common Descent, he makes the following profoundly insightful statement: “The difficulty with the classical Darwinian outlook, as Alfred North Whitehead long ago pointed out, is that it sees evolution as a ‘procession of forms,’ when the focus should instead be on the process that produces them—on the gem, not the reflections from its facets.

“The reality of HGT is forcing us to the Whiteheadian point of view, making us think more about the process and less about the detailed forms it generates. From this perspective, we will see that there was not one particular primordial form, but rather a process that generated many of them, because only in this way can cellular organization evolve.” *Ibid.*, 8745.

directionality, is not only consistent with Christianity, but actually resonates with the notion of the self-emptying love of God in Jesus Christ; and finally 5) suggest that we are called through an ecological imperative to embrace our evolutionary story, to listen to our “genetic coding,” and to reclaim our grounding as a species in the natural world.

### Epigenetics and the Genome in Context

The last three or four decades have seen the gradual emergence of a new field in developmental and evolutionary biology called *epigenetics*.<sup>3</sup> One commonly accepted definition of epigenetics is “the study of mitotically and/or meiotically heritable changes in gene function that cannot be explained by changes in DNA sequence.”<sup>4</sup> Under this definition, epigenetics would involve studying processes such as methylation patterns in DNA (chemical modification of certain nucleotides in a DNA sequence), parental imprinting of genes (differential marking of genes from mother versus father), and gene silencing (abolishment of gene activity by various means). But some biologists today are taking a broader view of epigenetics, one that includes, in addition to the above processes, phenomena that are independent of variation in genes. Such a definition overturns a gene-centric view and, “instead of focusing on the relatively static or immutable genetic system, focuses on the multi-layered contexts surrounding and interacting with the genome.”<sup>5</sup>

Two examples from the scientific literature will be presented to show that cellular components other than genes can affect the phenotype of an organism. The

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<sup>3</sup>The term epigenetics was coined by the visionary developmental biologist Conrad H. Waddington (1905–1975), who postulated that “the phenotype [of a developing organism]—at any instance—is the result of the interrelations among genetic processes, their potentialities and constraints, cytoplasmic differentiations, and the external environment.” L. Van Speybroeck, “From Epigenesis to Epigenetics: The Case of C.H. Waddington,” *Annals of the New York Academy of Sciences* 981 (December 2002): 61–81. In considering the role of genes in development, Waddington believed that organismal development followed an epigenetic trajectory that is *canalized*, or genetically buffered, against mutational or environmental perturbations by “the complex interrelations between elements and processes of the living system.” *Ibid.*, 72. According to Waddington, what controls “the entire epigenetic landscape [of a developmental process] is not just the genes and their products, but gene-gene interactions and gene-environment interactions.” *Ibid.*, 73. Thus, Waddington’s genetic holism differs markedly from the one-gene-one-enzyme hypothesis proffered by Beadle and Tatum in the 1940s. G. Beadle and E. Tatum, “Genetic Control of Biochemical Reactions in *Neurospora*,” *Proceedings of the National Academy of Sciences USA* 27 (1941): 499–506. Furthermore, we can see that today’s post-genomic efforts to map protein-protein interactions that occur within the proteome (the protein complement expressed by a genome) during different cellular processes were anticipated by Waddington’s holistic view.

<sup>4</sup>V.E.A. Russo, R.A. Martienssen, and A.D. Riggs, eds., *Epigenetic Mechanisms of Gene Regulation* (Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1996), 1.

<sup>5</sup>G. Van de Vijver, L. Van Speybroeck, and D. De Waele, “Epigenetics: A Challenge for Genetics, Evolution, and Development?” *Annals of the New York Academy of Sciences* 981 (December 2002): 1.

first example is the case of “transgenerational epigenetic inheritance” found in what are known as agouti mice.<sup>6</sup> The product of the *agouti* gene causes hair follicle melanocytes to switch from the synthesis of black to the synthesis of yellow hair pigment. Variable expression of the gene causes a range of coat colors within the same litter, from yellow to mottled to pseudoagouti (black), the last representing a complete reversion of coat color. The variable expression correlates with partial or complete silencing, via methylation, of a control region within a retrotransposon (a mobile DNA element of viral origin) located just upstream of the *agouti* gene. The partial or complete gene silencing is then followed by the subsequent mitotic inheritance of the methylated epigenetic state.

It is the incomplete erasure of the epigenetic marks during development that leads to the inheritance of the mottled and pseudoagouti phenotypes. Furthermore, the phenotypic heterogeneity arises independently of genetic and environmental differences. Rakyan and coworkers stress that such epigenetic inheritance is not Lamarckian<sup>7</sup> since it is not directed (willed by the organism), but arises from “the random failure to completely erase marks at certain alleles during development.”<sup>8</sup> They also note that since transposons are present in forty-two percent of human nuclear chromosomal DNA, “non-Mendelian [epigenetic] inheritance could be occurring at a large number of loci in humans.”<sup>9</sup>

A second example of how epigenetic factors can influence gene expression during development is provided by the small temporally-expressed RNAs (stRNAs) that control developmental timing in the nematode worm *Caenorhabditis elegans*. Two such stRNAs in *C. elegans* are encoded by the genes *lin-4* and *let-7*. These two stRNAs act by binding to the tails of their target messenger RNAs (mRNAs); this results in destruction of the target mRNA molecules and an overall drop in the level of production of protein from *agouti* mRNA.<sup>10</sup> Such downregulation controls the timing of developmental stages in *C. elegans*. Whereas the *lin-4* stRNA controls cell fate transitions in early larval development, the *let-7* stRNA controls later transitions; together, they act as “molecular ringmasters” of developmental timing.

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<sup>6</sup>V.K. Rakyan et al., “The Marks, Mechanisms and Memory of Epigenetic States in Mammals,” *Biochemical Journal* 356.1 (May 15, 2001): 1–10.

<sup>7</sup>Jean-Baptiste Lamarck was a contemporary of Charles Darwin who believed in the inheritance of acquired characteristics. The common example of Lamarck’s theory of evolution is that of the giraffe, who evolved to have a long neck because the ancestor of giraffes strove to reach leaves in trees, for example, by stretching his neck. J.-B. Lamarck, *Zoological Philosophy: An Exposition with Regard to the Natural History of Animals* (Chicago: University of Chicago Press, 1984, 1809), 122. Rakyan et al. are arguing that, since the embryos under consideration expended no effort in achieving a certain phenotype, the inheritance is not Lamarckian.

<sup>8</sup>Rakyan et al., *Marks, Mechanisms and Memory*, 8, emphasis added.

<sup>9</sup>Ibid.

<sup>10</sup>D. Banerjee and F. Slack, “Control of Developmental Timing by Small Temporal RNAs: A Paradigm for RNA-Mediated Regulation of Gene Expression,” *BioEssays* 24.2 (February 2002): 119–129.

Since embryonic spatial patterning in general (for example, body plan formation, limb formation, or in the case of *C. elegans*, larval stage) is often the result of a temporal sequence of gene expression events, mutations in the genes controlling timing of expression can result in morphological changes. Thus, mutations in these genes that control timing can result in variation that, when acted upon by natural selection, can lead to speciation.

It is important to emphasize that, although encoded by genes, stRNAs have an epigenetic effect because they interfere with gene expression beyond the level of the gene itself, in this case at the level of translation of mRNA into protein. Analysis of the genomes of metazoans (multicellular animals), including the human genome, reveals that genes for small noncoding RNAs are present throughout this group of organisms. Moreover, the fact that ninety-eight percent of the genomes of higher eukaryotes such as humans is made up of non-protein-coding sequences has led some biologists to wonder if something fundamental is lacking in our perspective. For example, biologist John Mattick argues that the recent discoveries of vital regulatory roles for noncoding RNAs “suggest that a complex network of RNA signaling with a sophisticated infrastructure operates in higher eukaryotes.”<sup>11</sup> Mattick further states that the surprisingly high level of DNA sequence homology within these noncoding regions from various mammalian genomes (humans, mice, and others) suggests that “far from being evolutionary junk, introns and other noncoding RNAs form the primary control architecture that underpins eukaryotic differentiation and development.”<sup>12</sup>

What the examples of the agouti mice and the stRNAs of the nematode *C. elegans* point out is that it is not genes per se, but rather *the genome in context* that is important for understanding biological development and evolution, and therefore, the place of humans in the web of life. These examples argue for an organic view of life rather than a reductionistic view. In the organic view, “complex wholes are inherently greater than the sum of their parts in the sense that the properties of each part are dependent upon the context of the part within the whole in which they operate.”<sup>13</sup> Further, “the properties at one level of complexity (for instance, tissues) cannot be ascribed directly to their component parts but arise only because of the interactions among the parts.”<sup>14</sup> Such properties are said to be *emergent*.

Organicism is the philosophical opposite of reductionism, which postulates that all things, including living things, can be completely explained by the properties of their component parts. As such, organicism is diametrically opposed to strict neo-Darwinism, especially the extreme views of Richard Dawkins (“selfish DNA”)<sup>15</sup>

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<sup>11</sup>J.S. Mattick, “Non-coding RNAs: The Architects of Eukaryotic Complexity,” *EMBO Reports* 2.11 (November 2001): 989.

<sup>12</sup>*Ibid.*, 990.

<sup>13</sup>S.F. Gilbert and S. Sarkar, “Embracing Complexity: Organicism for the 21st Century,” *Developmental Dynamics* 219.1 (September 2000): 1–9.

<sup>14</sup>*Ibid.*

<sup>15</sup>R. Dawkins, *The Selfish Gene* (Oxford: Oxford University Press, 1990, 1976).

and Edward O. Wilson (sociobiology),<sup>16</sup> who articulate a belief in genetic determinism. For Dawkins and Wilson, genes are not only the sole units of heredity; they also are the sole determinants of behavior.

We see, then, that scientific discoveries in epigenetics are weakening the grip that the Central Dogma—the belief that genes alone determine the essential characteristics of life—has had on biology. A broader, more holistic view of the genome is coming into focus. Genes are still important, but they are not quite the agents of centralized control they have been made out to be.

### **Both Neo-Darwinism and Intelligent Design are Preformationistic**

Preformationism, which arose in the seventeenth century, is the belief that “all living beings existed preformed inside their forebears in the manner of a Russian doll, put there by God at the beginning of Creation, with a precise moment established for each one to unfold and come to life.”<sup>17</sup> With preformationism, development is simply an unfolding of what was already present. A prominent preformationist was the French embryologist Charles Bonnet (1720–1793), who is best known for his conception of a “great chain of being” connecting all inanimate and animate objects in the universe, from minerals to plants to animals and, ultimately, to humans at the top.<sup>18</sup> In his book *Ontogeny and Phylogeny*, Stephen Jay Gould writes that

Bonnet extended to the entire universe the basic philosophical tenet of his preformationistic beliefs about ontogeny [embryonic development]—development is only apparent; it represents the unfolding of structures preformed at the creation itself. God, the clockwinder, had not only ordained the laws of the universe; He had created all its structures as well: one creation followed by the complete evolution of all preordained structure to the appointed end of time.<sup>19</sup>

Van Speybroeck et al. describe how, with the beginning of the search for the material basis of the determinants of Mendelian inheritance in the early twentieth century, a gene-centric view began to take shape. This view held that the sought-after determinants of inheritance (genes) control all functions of the cell, and are the “preformed hereditary units” that guide the production and inheritance of phenotypic characteristics.<sup>20</sup> Later, the physical manifestations of genes were found to occur on chromosomes, and by the middle of the twentieth century, the double helix, the structure of genes, and of the genetic code were discovered. After this, “genes

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<sup>16</sup>E.O. Wilson, *Sociobiology: The New Synthesis, Twenty-fifth Anniversary Edition* (Cambridge: Harvard University Press, 2000).

<sup>17</sup>C. Pinto-Correia, *The Ovary of Eve: Egg and Sperm and Preformationism* (Chicago: University of Chicago Press), 3. Quoted in L. Van Speybroeck, D. De Waele, and G. Van de Vijver, “Theories in Early Embryology: Close Connections between Epigenesis, Preformationism, and Self-Organization,” *Annals of the New York Academy of Sciences* 981 (December 2002): 14.

<sup>18</sup>S.J. Gould, *Ontogeny and Phylogeny* (Cambridge: Harvard University Press, 1977), 23, quoting C. Bonnet, *Contemplation de la Nature* (Amsterdam: Marc-Michel Rey, 1764), 27.

<sup>19</sup>Gould, *Ontogeny and Phylogeny*, 22.

<sup>20</sup>Van Speybroeck et al., “Theories in Early Embryology,” 32.

... were attributed with expanding responsibilities: inheritance, development, evolution, hereditary variation, and so forth. A new form of preformation seemed to be born.”<sup>21</sup> Van Speybroeck et al. comment that “the molecular revolution of the twentieth century brought forth metaphors like *genetic information*, *genetic program*, and *gene-centrism*—often considered to be modern preformationist notions, as they tend to present the genome as an instruction manual containing all the essential information to make an organism.”<sup>22</sup>

From this, one can see how the gene-centric view of neo-Darwinism is preformationistic. In this respect, neo-Darwinism is similar to intelligent design theory, which also is preformationistic. An updated version of this theory recently has been promoted by biochemist Michael Behe in his book *Darwin's Black Box*,<sup>23</sup> in which he argues that Darwinian evolution cannot explain the “irreducible complexity” found in living cells. Intelligent design theory, as a branch of creationism, is preformationistic because it proposes the existence of a static, unchanging order in the universe created by God at the beginning of time. However, as theologian John Haught rightly points out:

Although they remain rancorous antagonists, both materialist scientists [extreme neo-Darwinists such as Richard Dawkins and E. O. Wilson] and “intelligent design” theorists [Michael Behe] share the compulsion to suppress a vibrant sense of life’s openness to new creation. Almost by definition, scientific materialism leaves out everything that common wisdom means by “life.” But the focus of much religious thought on “intelligent design” likewise turns away from the novelty and instability without which life is reduced to death.<sup>24</sup>

Haught asks: “But what if ‘God’ is not just an originator of order but also the disturbing wellspring of *novelty*? And, moreover, what if the cosmos is not just an ‘order’ (which is what *cosmos* means in Greek) but a still unfinished *process*? Suppose we look carefully at the undeniable evidence that the universe is *still* being created [emphasis Haught’s].”<sup>25</sup> And, finally, he writes:

Darwin has gifted us with an account of life whose depth, beauty, and pathos—when seen in the context of the larger cosmic epic of evolution—expose us afresh to the raw reality of the sacred and to a resoundingly meaningful universe.<sup>26</sup>

It is important to point out at this juncture that it is not Darwinism, but rather *neo-Darwinism*,<sup>27</sup> with its strict gene-centric view, that is being overturned by re-

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<sup>21</sup>Ibid.

<sup>22</sup>Ibid.

<sup>23</sup>M. Behe, *Darwin's Black Box: The Biochemical Challenge to Evolution* (New York: Free Press, 1996).

<sup>24</sup>J.F. Haught, *God After Darwin: A Theology of Evolution* (Boulder, CO: Westview Press, 2000), 5.

<sup>25</sup>Ibid, 6.

<sup>26</sup>Ibid, 2.

<sup>27</sup>It should be pointed out that John Haught in *God After Darwin* does not make a distinction between the original theory of Darwin and the neo-Darwinism that was forged

cent epigenetic discoveries. It is not Darwin's theory of "descent with modification" that is being called into question. It is not the *fact* of biological evolution that is in question, but rather the *mechanism* of evolution, how it takes place. Epigeneticists are still staunch believers in the fact of biological evolution; they just disagree with the gene-centric view put forth by neo-Darwinians regarding how evolution proceeds. As a side note, it is interesting that creation scientists often will use this disagreement within the community of evolutionary biologists concerning the mechanism of evolution to attempt to discredit the fact of evolution.<sup>28</sup> For example, a recent publication has used the growing body of evidence for a functional role for noncoding genomic DNA (so-called "junk" DNA) to suggest that this proves the existence of "intelligent design" by God.<sup>29</sup>

What epigeneticist researchers and scientists such as Gould are showing us is that one does not have to be a strict neo-Darwinian like Wilson or Dawkins to believe in evolution. Evidence is mounting that mechanisms of evolutionary change are much broader and more holistic than a gene-centric view dictates. And, as we will see, this opens the door for a creative God in evolution.

### **The Evolutionary Story Resonates with Christianity**

Catholic theologian John Haught writes that, according to Karl Rahner, "the central content of Christian faith is that the infinite mystery of God pours itself generously, fully, and without reservation into creation."<sup>30</sup> Since the divine infinity cannot be received instantaneously by a finite cosmos, however, reception would need to take place gradually. Thus, "a finite world could 'adapt' to an infinite source of love only by a process of gradual expansion and ongoing self-

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from the "modern synthesis" of Darwin's theory with genetics. It should also be pointed out, however, that many of the discoveries in epigenetics have taken place only within the last few years.

<sup>28</sup>This has the effect of solidifying the rigid neo-Darwinist position within evolutionary biology since any deviation from the Central Dogma might be seen as giving in to the creationists. An interesting example of this is seen with Gould, who has been accused by some evolutionists of strengthening the position of creationists by proposing that mechanisms other than the gradualism of microevolution, namely punctuated equilibrium and historical contingency, can explain macroevolutionary events. Some theologians, on the other hand, have accused Gould of widening the chasm between evolutionary science and religion by adamantly insisting that science and religion do not overlap. Nevertheless, philosopher Michael Ruse collegially writes that: "Stephen Jay Gould ... is one who sees no conflict between evolution and religion. Raised a secular Jew, he describes himself as an agnostic, but he has always struck me as being closer to God than many conventional believers.... Gould has argued repeatedly and vehemently that science and religion do not and (properly understood) cannot clash." M. Ruse, *Can a Darwinian Be a Christian? The Relationship between Science and Religion* (Cambridge: Cambridge University Press, 2001), 10.

<sup>29</sup>Richard Deem, "When Junk DNA Isn't Junk," [<http://www.evidence.info/design/junkdna.html>] (May 21, 2003).

<sup>30</sup>Haught, *God After Darwin*, 39.

transcendence, the external manifestation of which might appear to science as cosmic and biological evolution.”<sup>31</sup> In this manner, Haught suggests how the theology of Rahner might be used to build a bridge between evolution and Christianity.

Haught goes further, writing that only by “letting the world be itself,” could God unconditionally pour out his love into the world, and “only a relatively independent universe . . . could be intimate with God. Theologically interpreted, therefore, the epic of evolution is the story of the world’s struggle—not always successful or linearly progressive—toward an expansive freedom in the presence or self-giving grace.”<sup>32</sup> Haught relates how such a model of “persuasive love” is similar to Whiteheadian process theology, which seeks to interpret biblical teachings in terms consistent with “the evolutionary character of the world.”<sup>33</sup> But it is Haught’s “theology of divine humility” that most strongly resonates with the spirit of evolution. It is the belief that Christ “emptied himself” and became a servant of us all (Phil 2:5–11) that lies at the heart of Christianity. As Haught points out, “this image [of an incarnate God who suffers along with creation] breaks through the veil of our pedestrian projections of the absolute, and does so in such a way as to bring meaning to all of life’s suffering, struggle, and loss.”<sup>34</sup> In a commentary on both materialistic determinism and intelligent design theory, he writes: “[A] theology of divine humility makes room for true novelty to spring spontaneously into being—a feature logically suppressed by deterministic materialist interpretations, as well as by the notion that the universe is simply the unfolding of an eternally fixed divine design or plan.”<sup>35</sup> In rare agreement with Stephen Jay Gould, who has argued that historical contingency is a source of macroevolutionary change,<sup>36</sup> Haught states that “the randomness, struggle, and seemingly aimless meandering that the evolutionary story of life discloses . . . are consistent with the idea that the universe is the consequence of an infinite love.”<sup>37</sup> Finally, he writes that a theology of divine humility or divine self-emptying love, as an evolutionary theology, “expands this picture of God’s suffering so as to have it embrace also the struggles of the entire universe and not just our own species’ brief history here.”<sup>38</sup> Thus, we have in John Haught’s theology of divine self-emptying love a demonstration that Christianity not only is consistent with the theory of evolution, but also resonates with it on a very deep level.

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<sup>31</sup>Ibid.

<sup>32</sup>Ibid, 40.

<sup>33</sup>Ibid, 41.

<sup>34</sup>Ibid, 50.

<sup>35</sup>Ibid, 54.

<sup>36</sup>S.J. Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (New York: W.W. Norton and Company, 1989).

<sup>37</sup>Haught, *God After Darwin*, 113.

<sup>38</sup>Ibid, 51.

## Why We Must Embrace Our Evolutionary Story

Whatever the particular manner in which God acts through evolution, there is one thing of which we can be sure: the evolutionary story is our story. This is true whether we are talking about the evolution of the universe as a whole or the evolution of Earth and its living creatures. In fact, there cannot be any real distinction between these two series of events since the evolution of Earth and its creatures is only possible because the universe came into existence precisely in the way it did. One might even say that the initial “flaring forth” of the universe anticipated the rise of life on Earth, although such anticipation in no way implies causality. This notion is expressed by cosmologist Brian Swimme and theologian Thomas Berry in their book *The Universe Story*:

All that exists in the universe traces back to this exotic, ungraspable seed event, a microcosmic grain, a reality layered with the power to fling a hundred billion galaxies through vast chasms in a flight that has lasted fifteen billion years. The nature of the universe today and of every being in existence is integrally related to the nature of this primordial Flaring Forth. The universe is a single multiform development in which each event is woven together with all the others in the fabric of the space-time continuum.<sup>39</sup>

The ongoing effort to sequence the genomes of increasing numbers of Earth’s creatures is revealing just how genetically similar we all are to each other. We all share the same evolutionary story. All earthly creatures are bound together, interconnected, by a common biological heritage. Furthermore, ecology reveals that we are all dependent on each other. Indeed, Earth can be thought of as an organic, self-regulating whole, analogous to a living organism.<sup>40</sup> Even the inanimate parts of Earth—the soil, the rocks, and the atmosphere, for example—are nevertheless part of this living whole. Each is formed in the gentle crucible of life on this evolving (and revolving) blue and white planet that is our home and the home of myriad other living creatures. Soil is formed by the action of soil-dwelling animals and microorganisms that break down decaying organic matter; sedimentary rocks are formed from the bodies of millions of tiny marine creatures pressed together on the ocean floor; and Earth’s atmosphere, with its exact composition of oxygen, nitrogen, and carbon dioxide, is constantly being maintained by the coordinated efforts of plants and photosynthetic bacteria and oxygen-respiring animals. Earth’s living ecosystems thus are globally connected. Evolutionary biologist Niles Eldredge writes:

The flow of energy between species of microbes, fungi, plants, and animals in any local setting is connected laterally with adjacent regions. Local systems are linked into regional systems.... Regional systems are themselves linked up into

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<sup>39</sup>B. Swimme and T. Berry, *The Universe Story: From the Primordial Flaring Forth to the Ecozoic Era, A Celebration of the Unfolding of the Cosmos* (San Francisco: HarperCollins Publishers, 1992), 21.

<sup>40</sup>James Lovelock has proposed what is known as the “Gaia Theory,” which states that the earth is analogous to a living organism in the sense that it is a self-regulating, autopoietic, and holistic system. See J. Lovelock, *The Ages of Gaia: A Biography of Our Living Earth* (New York: Norton Press, 1988).

continental systems. And the whole is integrated through patterns of atmospheric and oceanic circulation. There is a global interconnectedness to the world's environment, and Earth's living creatures are very much a part of that interconnectedness.<sup>41</sup>

We risk irreparably damaging Earth's ecosystems and its basic life systems if we do not curb our current actions. We are plundering the natural world around us. Evolutionary biology and ecology tell us that biological diversity (and human diversity, for that matter) is important for the health of Earth's ecosystems, yet we continue to drive species into extinction by destroying their habitats.

Global warming, caused by massive emissions of carbon dioxide into the atmosphere from cars and industry, is apparently already showing signs of changing climate and disrupting ecosystems. There is evidence that our release of toxic chemicals into the atmosphere is destroying the layer of ozone that protects us from dangerous ultraviolet rays. Thomas Berry identifies secular Western society, with its scientific and technological capabilities, as the source of our disjunction with the natural world. He writes that our society "has broken the primary law of the universe, the law of integrity of the universe, the law that every component member of the universe should be integral with every other member."<sup>42</sup> Berry emphasizes that we must listen to our "genetic coding" through which is expressed our "bonding with the larger dimensions of the universe."<sup>43</sup> He further writes:

The genetic coding that gives to the human its species identity is integral with [the] larger complex of codings whereby the universe exists, whereby the earth system remains coherent within itself and capable of continuing the evolutionary process.<sup>44</sup>

The problem, he realizes, is that our "cultural coding" is not in synchrony with our genetic coding. The solution is a "reimmersion in the natural forces out of which our cultural achievements came about originally."<sup>45</sup>

Reflecting the words of Berry, it is imperative that we return to our grounding as a species in the natural world. We must listen to our "genetic coding," which we now know is really the *epigenetic* coding by which we are connected to our environment.<sup>46</sup> We must strive to create rituals to celebrate our evolutionary story. We

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<sup>41</sup>N. Eldredge, *Life in the Balance: Humanity and the Biodiversity Crisis* (Princeton, NJ: Princeton University Press, 1998), 150.

<sup>42</sup>Berry, *Dream of the Earth*, 202.

<sup>43</sup>Ibid, 196.

<sup>44</sup>Ibid, 208.

<sup>45</sup>Ibid, 201.

<sup>46</sup>Developmental biologist Scott Gilbert, who coined the term "ecological developmental (Eco-Devo) biology," emphasizes the direct importance of environment on development, hence evolutionary change. Gilbert writes: "A particular environment can elicit different phenotypes from the same genotype. Development usually occurs in a rich environmental milieu, and most animals are sensitive to environmental cues. The environment may determine sexual phenotype, induce remarkable structural and chemical adaptations according to

must, at the same time, develop a more intimate awareness of our relatedness to Earth's creatures and to Earth herself. Science, in many ways, already is helping us in this effort, but along with the scientific insights we gain must come an ecological awareness. Everything depends on how we use the science and technology we develop. For example, a gene-centric view and a lack of ecological perspective may lead us to genetically modify other creatures and ourselves in ways that are harmful. Throughout, our response should not be to abandon science and technology as we "return to nature," but rather find ways in which science and technology can lead us into a sustainable future consistent with our evolutionary heritage.

### **Listening to Our Epigenetic Coding**

The emerging field of epigenetics reveals that a deterministic view of genes as controllers of all cellular function is incorrect. Rather, it is the genome in the context of its cytoplasmic and external environments that is important for development and for evolution. Analysis of genomes shows that living creatures on Earth are profoundly interrelated; this is because we share a common evolutionary story. This story of the evolution of life, our story, is one that resonates deeply with the Christian belief in a God who loves us with an infinite, self-emptying love.

Ecology shows that all living things are deeply interconnected with each other and with the life systems of Earth. Humans, especially in the last several centuries, have increasingly plundered the natural world, so much so that the life systems of the planet are at risk. In order to have a sustainable future on Earth, it is imperative that we listen to our genetic (or epigenetic) coding and find a way to regain a harmonious relationship with nature. We humans are now truly a global species, and the future of Earth rests in our hands. Although we do not stand at the summit of evolution and are not life's crowning achievement, we nevertheless are special. Due to our reflective consciousness, we alone among Earth's creatures have the ability to step outside of ourselves and see our place in the universe. And so, we are special because we have a special role to play: to celebrate the dance of life in all its fullness and to strive to protect life in all of its rich diversity on Earth. May we not fail in this task.

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the season, induce specific morphological changes that allow an individual to escape predation, and induce caste determination in insects. The environment can also alter the structure of our neurons and the specificity of our immunocompetent cells.... The phenotype depends to a significant degree on the environment, and this is a necessary condition for integrating the developing organism into its particular habitat." S. Gilbert, "Ecological Developmental Biology: Developmental Biology Meets the Real World," *Developmental Biology* 233.1 (May 1, 2001): 8.