

The Meanings of Evolution

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“**E**volution and the theories of evolution are fundamentally different things,” testified zoologist Maynard M. Metcalf, the first expert witness for the defense in the 1925 Scopes trial. Metcalf’s observation at the “trial of the century” officially marked the beginning of public discussion of the different meanings of *evolution* for the purposes of science education. “The fact of evolution is a thing that is perfectly and absolutely clear,” Metcalf explained, “but there are many points—theoretical points as to the methods by which evolution has been brought about—that we are not yet in possession of scientific knowledge to answer.”¹

Metcalf’s statement suggested, as many modern biologists have noted, that the term *evolution* can mean different things. His comment also suggested that not all senses of evolution have the same epistemological standing. We can assert confidently that evolution “has occurred,” Metcalf explained, but we may be more uncertain about how it occurred.

Metcalf made this distinction to show the court that critique of evolution in one sense did not necessarily count as critique of evolution in other senses. To assume otherwise would be to commit the logical fallacy of equivocation. He feared that confusion between the fact of evolution and the theory of evolution would justify excluding all teaching about evolution

simply because some aspects of evolutionary theory did not have the same degree of confirmation as others.²

Of course, science teachers must also avoid equivocation, if only because they don't want to confuse their students. Yet for biology teachers, this may prove difficult—given the many separate meanings that the term *evolution* has come to possess. As Yale biologist Keith Stewart Thomson has shown, the term *evolution* may have more than just two meanings.³

Equivocal usage poses a practical difficulty for science teachers. Good science teachers must define terms carefully and use them consistently to avoid conflating different ideas. Good biology teachers must tease apart the distinct ideas associated with evolution to help students to evaluate each idea separately and to distinguish evidence and observations, on the one hand, from inferences and theories, on the other.

Thomson identified at least three distinct meanings associated with evolution in contemporary biology: change over time, common ancestry, and the natural mechanisms that produce change in organisms.⁴ This essay will further refine these distinctions and present six distinct meanings. In so doing, we want to help science educators distinguish well-established from less well-established senses of the term *evolution*. We also want to help teachers avoid false controversies over senses of the term that enjoy wide scientific confirmation and support and to help them explain the real controversies that remain over more theoretically contentious propositions.

The following definitions develop and distinguish those multiple meanings, which we propose as guideposts for clear biology instruction.

I.

Principal Meanings of Evolution in Biology Textbooks

1. Change over time; history of nature; any sequence of events in nature.
2. Changes in the frequencies of alleles in the gene pool of a population.
3. Limited common descent: the idea that particular groups of organisms have descended from a common ancestor.
4. The mechanisms responsible for the change required to produce limited descent with modification, chiefly natural selection acting on random variations or mutations.
5. Universal common descent: the idea that all organisms have descended from a single common ancestor.

6. “Blind watchmaker” thesis: the idea that all organisms have descended from common ancestors solely through an unguided, unintelligent, purposeless, material processes such as natural selection acting on random variations or mutations; that the mechanisms of natural selection, random variation and mutation, and perhaps other similarly naturalistic mechanisms, are completely sufficient to account for the appearance of design in living organisms.

Let us look at these six definitions of evolution.

1. *Evolution as Change Over Time.* Nature has a history; it is not static. Natural sciences deal with evolution in its first sense—change over time in the natural world—when they seek to reconstruct series of past events to tell the story of nature’s history.⁵ Astronomers study the life cycles of stars; geologists ponder the changes in the earth’s surface; paleontologists note changes in the types of life that have existed over time, as represented in the sedimentary rock record (fossil succession); biologists note ecological succession within recorded human history, which may have, for example, transformed a barren island into a mature forested island community. Although the last example has little to do with neo-Darwinian evolutionary theory, it still fits within the first general sense of evolution as natural historical progression or sequence of events.
2. *Evolution as Gene Frequency Change.* Population geneticists study changes in the frequencies of alleles in gene pools. This very specific sense of evolution, though not without theoretical significance, is closely tied to a large collection of precise observations. The melanism studies of peppered moths, though currently contested, are among the most celebrated examples of such studies in microevolution.⁶ For the geneticist, gene frequency change is “evolution in action.”
3. *Evolution as Limited Common Descent.* Virtually all scientists (even many creationists) would agree that Darwin’s dozen or more famed Galapagos Island finch species are probably descended from a single continental South American finch species. Although such “evolution” did not occur during the brief time scale of the lives of scientists since Darwin (as in the case of the peppered moth), the pattern of biogeographical distribution of these birds strongly suggests to most scientists that all of these birds share a common ancestor. Evolution defined as “limited common descent” designates the scientifically uncontroversial idea that many different varieties of similar organisms within different species, genera, or even families are related by common ancestry. Note that it is possible for

some scientists to accept evolution when defined in this sense without necessarily accepting evolution defined as universal common descent—that is, the idea that all organisms are related by common ancestry.

4. *Evolution as a Mechanism that Produces Limited Change or Descent with Modification.* The term *evolution* also refers to the mechanism that produces the morphological change implied by limited common descent or descent with modification through successive generations. Evolution in this sense refers chiefly to the mechanism of natural selection acting on random genetic variation or mutations. This sense of the term refers to the idea that the variation/selection mechanism can generate at least limited biological or morphological change within a population. Nearly all biologists accept the efficacy of natural selection (and associated phenomena, such as the founder effect and genetic drift) as a mechanism of speciation. Even so, many scientists now question whether such mechanisms can produce the amount of change required to account for the completely novel organs or body plans that emerge in the fossil record. Thus, almost all biologists would accept that the variation/selection mechanism can explain relatively minor variations among groups of organisms (*evolution* meaning #4), even if some of those biologists question the *sufficiency* of the mechanism (*evolution* meaning #6) as an explanation for the origin of the major morphological innovations in the history of life.
5. *Evolution as Universal Common Descent.* Many biologists commonly use the term *evolution* to refer to the idea that all organisms are related by common ancestry from a single living organism. Darwin represented the theory of universal common descent or universal “descent with modification” with a “branching tree” diagram, which showed all present life forms as having emerged gradually over time from one or very few original common ancestors. Darwin’s theory of biological history is often referred to as a monophyletic view because it portrays all organisms as ultimately related as a single family.

In the *Origin of Species*, Charles Darwin argued for his theory of universal common descent on the grounds that it best explained a variety of biological evidences, including fossil succession, biogeographical distribution of species (such as the Galapagos finches), the existence of apparently suboptimal or useless organs, and the existence of homologous structures and embryological similarities in otherwise disparate organisms.

The presumed strength of the case for universal common descent has led many scientists to treat the theory of universal common descent as though it were a fact. Maynard M. Metcalf and more recently Stephen Jay Gould and Michael Ruse have been among prominent advocates of the idea that evolution defined as “universal common ancestry” qualifies as a fact. Each of these advocates articulated this view while serving as an expert witness in a creation-evolution court trial. Yet as one of us (Meyer) has argued in response to Michael Ruse, universal common descent is not, strictly speaking, a fact.⁷ As Meyer noted:

Strictly speaking, common descent is an abductive or historical inference, as Professor Ruse himself acknowledges when he speaks more accurately of “inferring historical phylogenies.” As defined by C. S. Peirce, abductive inferences attempt to establish past causes by viewing present effects. (As such, it is more accurate to refer to common descent as a theory about facts, i.e., a theory about what in fact happened in the past.) Unfortunately, such theories, and the inferences used to construct them, can be notoriously underdetermined. As Elliot Sober points out, many possible pasts often correspond to any given present state. Establishing the past with certainty, or even beyond reasonable doubt, can therefore, be very difficult.⁸

Although Darwin’s monophyletic view of life’s history has reigned as the dominant theory of the history of life during most of the twentieth century, a number of biologists now question that view on evidential grounds. These scientists now see the present diversity and disparity of organisms as having originated from many separate ancestral forms and lines of descent. Those favoring a so-called polyphyletic or multiple separate origins view of life’s history now cite evidence from paleontology, embryology, biochemistry, and molecular biology in support of their view.⁹

Evolution in the fifth sense not only specifies that all life shares a common ancestry, it implies that virtually no limits exist to the amount of morphological change that can occur in organisms. It assumes that relatively simple organisms can, given adequate time, change into much more complex or different organisms, and these organisms can in turn be altered by the evolutionary process to become yet new organisms. Thus, evolution in this sense entails the idea of unbounded biological change. That view is now opposed by biologists who see biological change as limited and who favor a polyphyletic view of life’s history, in which many lineages of animals or plants arise separately (without genealogical connections) during the history of life.

Because Darwin's monophyletic interpretation of life's history is an inference from biological evidence, instructors should encourage students to understand and examine classical Darwinian arguments for that interpretation rather than simply presenting the interpretation as brute fact. Moreover, since several lines of evidence and many qualified scientists now challenge this theory of the history of life, the evidence for alternate polyphyletic theories of life's history should also be discussed and critically evaluated. Allowing students to see how scientists interpret the same biological evidence differently will help encourage evaluation and critical thinking skills. It will also allow students to understand the method of multiple competing hypotheses that scientists often employ to evaluate their data.

We will return to this fifth meaning of evolution in the last sections of this essay when we critique public statements about how evolutionary theory should be taught in public schools. At present, many public policy (and other) statements about how to teach evolution lapse uncritically into describing evolution (that is, universal common descent) as a fact.

In addition to the five definitions of evolution discussed thus far, an additional definition lies at the core of what evolutionary biology means to most scientists today.

6. *Evolution as the "Blind Watchmaker" Thesis.* The "blind watchmaker" thesis, to appropriate Richard Dawkins's clever term, stands for the Darwinian idea that all new living forms arose as the product of unguided, purposeless, material mechanisms, chiefly natural selection acting on random variation or mutation.¹⁰ Evolution in this sense implies that the Darwinian mechanism of natural selection acting on random variations (and other equally naturalistic processes) completely suffices to explain the origin of novel biological forms and the appearance of design in complex organisms. Although Darwinists and neo-Darwinists admit that living organisms appear designed for a purpose, they insist that such "design" is only *apparent*, not *real*, precisely because they also affirm the complete sufficiency of unintelligent natural mechanisms (that can mimic the activity of a designing intelligence) of morphogenesis. In Darwinism, the variation/selection mechanism functions as a kind of "designer substitute." As Dawkins summarizes the blind watchmaker thesis: "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 all life, has no purpose in mind. It has no mind and no mind's eye."¹¹

In addition to the theory of universal common ancestry, classical "Darwinism" affirmed this sixth meaning of evolution. As Harvard evolutionary biologist Ernst Mayr has explained: "The real core of Darwinism, however, is the theory of natural selection. This theory is so important for the Darwinian because it permits the explanation of adaptation, the 'design' of the natural theologian, by natural means, instead of by divine intervention."¹²

Or as Mayr put it recently:

First, Darwinism rejects all supernatural phenomena and causations. The theory of evolution by natural selection explains the adaptedness and diversity of the world solely materialistically. It no longer requires God as creator or designer (although one is certainly free to believe in God even if one accepts evolution). Darwin pointed out that creation, as described in the Bible and the origin accounts of other cultures, was contradicted by almost any aspect of the natural world. Every aspect of the "wonderful design" so admired by natural theologians could be explained by natural selection.¹³

Further, not just classical Darwinism but contemporary neo-Darwinism has also affirmed this sixth meaning of evolution. Since the 1940s, the blind watchmaker thesis has been supported by the neo-Darwinian synthesis—which combined Mendelian genetics with Darwin's theory of descent with modification. Neo-Darwinists proposed various types of random mutations as the creative engines giving natural selection the raw genetic material upon which to work. Many biologists before the 1940s had questioned the adequacy of Darwin's mechanism precisely because they worried that natural selection did not have an adequate source of variation upon which to operate. Neo-Darwinists argued that the phenomena of mutations solved that problem by providing natural selection an unlimited source of genetic change. Thus, they, like the classical Darwinists before them, again affirmed the complete sufficiency of the (now) neo-Darwinian mechanism as an explanation for new living forms on Earth (and the appearance of design that they manifest). As George Gaylord Simpson would assert in his classic 1967 book, *The Meaning of Evolution*: "Man is the result of a purposeless and natural process that did not have him in mind. He was not planned."¹⁴ As a result of the neo-Darwinian synthesis, biologists again assumed that a completely natural mechanism—natural selection acting on random mutations—could produce not only *limited* morphological change (and thus, patterns of limited common descent—evolution #3) but also

unlimited morphological change (and thus the pattern of *universal* common descent—evolution #5). Neo-Darwinists also assumed that the new mutation/selection mechanism could account entirely for the appearance of design in biological systems.

This view is reflected in many high school biology texts. As Kenneth Miller and Joseph Levine long asserted it in their popular text, “evolution works without plan or purpose.”¹⁵ Or as Purvis, Orians, and Heller tell students, “the living world is constantly evolving without any goals . . . evolutionary change is not directed.”¹⁶ Similarly, Douglas Futuyma, in his widely used college textbook, *Evolutionary Biology*, writes: “By coupling undirected, purposeless variation to the blind, uncaring process of natural selection, Darwin made theological or spiritual explanations of the life processes superfluous.”¹⁷ Francisco J. Ayala, president of the American Association for the Advancement of Science (AAAS) and chair of the National Academy of Sciences (NAS) steering committee for its 1999 edition of *Science and Creationism* (see analysis below), likewise speaks of Darwinism as having “excluded God as the explanation accounting for the obvious design of organisms.”¹⁸

The blind watchmaker thesis suggests that the neo-Darwinian mechanism (and other related ones) functions as a designer substitute; it plays the role of creator in the scientific account of biological origins. Thus, clearly, this sixth meaning of evolution does have larger metaphysical or worldview implications. Many philosophical naturalists or materialists find support for their worldview in neo-Darwinian theory for what seems to them good reasons. If neo-Darwinism is true, God’s creative activity (whether expressed discretely or gradually) would no longer be necessary to explain the origin of new living forms, since a strictly naturalistic mechanism would suffice. Thus, a strictly naturalistic worldview would seem to provide a simpler account of reality, or at least of biological reality, than a theistic one. Further, if neo-Darwinism is true, then the natural world does not display evidence of actual design, divine or otherwise—as most religious theists affirm. For both of these reasons, neither neo-Darwinism nor other materialistic origins theories taught in the public schools (such as the chemical evolutionary theory of the origin of the first life) are religiously or metaphysically neutral. All strictly materialistic origins theories, if true, have implications that would seem to make a materialistic worldview more plausible than a theistic one and would also contradict some deeply held religious beliefs.

Despite the confidence that many biologists and biology texts display in affirming the blind watchmaker thesis—*evolution* in the sixth sense—many scientists, including many biologists, have increasingly questioned the adequacy of the neo-Darwinian mechanism.¹⁹ Recently, a number of scientists have come to question whether natural selection acting on random variation can create the complex organs, molecular machines, and novel body plans that appear during the history of life. Such so-called macroevolutionary changes in the history of life—for example, the relatively sudden appearance of most extant and extinct animal phyla during the Cambrian explosion 530 million years ago—seem especially difficult to explain via the neo-Darwinian mechanism. As Gilbert, Opitz, and Raff have assessed the situation: “The Modern Synthesis is a remarkable achievement. However, starting in the 1970’s, many biologists began questioning its adequacy in explaining evolution. Genetics might be adequate for explaining microevolution, but microevolutionary changes in gene frequency were not seen as able to turn a reptile into a mammal or to convert a fish into an amphibian. Microevolution looks at adaptations that concern only the survival of the fittest, not the arrival of the fittest.”²⁰

Since the 1970s, many scientists have looked for additional naturalistic (or so-called self-organizational) mechanisms to show how extensive morphological innovation could arise—without, as yet, achieving much consensus or obvious success.²¹ Some scientists have questioned the sufficiency of the mutation/selection mechanism without proposing any alternatives. Still other scientists, such as Michael Behe, have proposed an alternative nonnaturalistic explanation for the origin of major innovations in the history of life, namely, the theory of intelligent design. Design theorists in general question the adequacy of the neo-Darwinian mechanism and see evidence of real (that is, intelligent) design, not just apparent design, in biology.

Of course, many defenders of the neo-Darwinian mechanism remain, especially in fields such as population genetics, zoology, comparative anatomy, and molecular biology. Nevertheless, given the diversity of opinion within the scientific community, scientific integrity would seem to require teaching students about the controversy that has emerged among scientists about the blind watchmaker thesis. Further, given the larger metaphysical or worldview implications of that thesis, religious neutrality would also seem to require (a) avoiding the issue of design or purpose altogether, in which case neither classical Darwinism nor neo-Darwinism could be taught (since both make explicit claims about the origin of the

appearance of design), or (b) teaching the controversy about the origin of this central feature of biological systems.

II.

1. Educational Policy Statements and Treatment of the “E” Word

We favor exposing students to scientific controversies. Teachers need not conceal the metaphysical or ideological issues that arise in the discussion of scientific theories. By allowing students to discuss and evaluate competing views despite their differing metaphysical implications, teachers may find that their students demonstrate a greater enthusiasm for science itself. By eschewing dogmatic presentations where evidence admits competing views, teachers will promote a scientifically and ideologically responsible curriculum. They may also promote a creative engagement by students that gives them a personal interest in the outcome of ongoing scientific discussions. Such engagement could help reverse the historic decline in student interest in science and in the number of science students, especially biology students, who drop science majors before completing their bachelor’s degrees.²²

Scientifically literate people know that nature has a history, that gene frequencies change, that at least limited common descent among organisms has occurred, and that natural selection has played a significant role in speciation and species modification. These first four meanings of evolution might aptly wear the label “mere evolution.” Unsurprisingly, few object to teaching mere evolution. Controversy develops, however, when scientists, teachers, or students want to evaluate evolution critically in the fifth or sixth senses of the term. Spokespersons for neo-Darwinism, which embraces evolution in both the fifth and sixth senses, often suggest that dissenting opinion about evolution in any sense is either ill-informed or intellectually perverse.

Nevertheless, those attempts to exclude scientific dissent often employ ambiguous or shifting definitions of the term *evolution*. Many defenders of evolution #5 and/or #6 will offer evidence and argument for evolution in the first four senses of the term and then treat evolution in the latter two senses as equally well established. In the following section, we will show how educational policy statements and advocates for evolution often equivocate in their discussion of evolution to the detriment of public understanding of the issues facing biologists and biology teachers.

2. "The Fact of Evolution": Conflating Meanings #1–3 with Meaning #5

A recent booklet, *Science and Creationism: A View from the National Academy of Sciences* (1999), defends teaching the subject of biological origins from an exclusively evolutionary perspective.²³ According to *Science and Creationism*, not only do alternative theories (such as intelligent design) fail to qualify as science, but evolution has been established beyond any reasonable doubt. The booklet's introduction argues that the "theory of evolution" is a scientific explanation "so thoroughly tested and confirmed" that it is "held with great confidence" and is "one of the strongest and most useful scientific theories we have." It even claims that evolution is so well established that it can legitimately be described as a fact. As the booklet explains, "Scientists most often use the word 'fact' to describe an observation. But scientists can also use fact to mean something that has been tested or observed so many times that there is no longer a compelling reason to keep testing or looking for examples. The occurrence of evolution in this sense is a fact. Scientists no longer question whether descent with modification occurred because the evidence supporting the idea is so strong."²⁴

Those statements aptly illustrate the ambiguity associated with the term *evolution* and the confusion that its unqualified use creates. Precisely which sense of evolution has been "so thoroughly tested and confirmed" that it "is held with great confidence" and can even be regarded as "a fact"? Mere evolution, or evolution #5 and/or #6? The NAS statement never specifies, though presumably it means to affirm the theory of universal common descent, evolution #5.

Indeed, the booklet often employs ambiguous (or shifting) definitions from one sentence to the next. The second-to-last sentence in the quotation asserts that "the occurrence of evolution" is a fact. And, of course, it may well be, depending upon which sense of evolution is meant. The phrase, "the occurrence of evolution," seems to imply evolution in the sense of change over time (evolution #1) or perhaps change in the frequency of expression of alleles (evolution #2). Certainly, evolution in these senses has occurred. Yet the next sentence affirms that "descent with modification" is so well established as to be an unquestioned fact. Throughout the booklet, "descent with modification" is equated with the theory of universal common descent (evolution #5), though technically it could refer either to limited or universal common descent (evolution #3 or #5). In any case, given the booklet's conventions, the last sentence of the quotation

seems to affirm a stronger meaning of evolution (evolution #5) than that affirmed in the previous sentence (evolution #1, #2, or possibly #3). Yet the booklet provides no additional justification for affirming this stronger meaning. As such, the passage commits the fallacy of equivocation.

The writers of the NAS booklet do, of course, seem aware that the term *evolution* can refer to different concepts. In particular, they make a distinction between *whether* evolution occurred (that is, the fact of evolution) and *how* (that is, the mechanism by which it occurred). Yet their attempt to clarify definitional matters on such grounds only confuses the issue further, as the following passage illustrates:

The scientific consensus around evolution is overwhelming. Those opposed to the teaching of evolution sometimes use quotations from prominent scientists out of context to claim that scientists do not support evolution. However, an examination of the quotations reveals that the scientists are actually disputing some aspect of *how* evolution occurs, not *whether* evolution occurs. For example, the biologist Stephen Jay Gould once wrote that “the extreme rarity of transitional forms in the fossil record persists as the trade secret of paleontology.” But Gould, an accomplished paleontologist and educator about evolution, was arguing about *how* evolution takes place. He was discussing whether the rate of change of species is slow or gradual or whether it takes place in bursts after long periods when little change takes place—an idea known as punctuated equilibrium.²⁵

This passage betrays confusion on several counts. First, scientists can affirm *that* evolution (in several different senses, #1–4) has occurred without necessarily affirming the theory of universal common descent. To say that evolution has occurred does not necessarily imply that enough morphological change has occurred to ensure that all organisms are connected by common ancestry. Thus, a scientist could affirm that evolution (#1–4) has occurred and yet doubt the universal common ancestry thesis. In fact, as noted above, many scientists do now take precisely that position. The simple twofold distinction (between “the” fact and the mechanism of evolution) in the NAS booklet obscures this possibility. There are many alleged “facts” of evolution, and the booklet does not distinguish among them.

Second, the “extreme rarity of transitional forms” does reflect negatively on evolution in the fifth sense—that is, it does seem to provide evidence against universal common descent. True, Stephen Gould does not question universal common descent, but he has reasons other than fossil data (molecular evidence, for example) for accepting the theory. The fossil evidence taken at face value, however, does suggest that, for example, the major

taxonomic categories of animals did arise separately within a very narrow window of geologic history. The absence of transitional precursors between the representatives of the new animal phyla strongly supports that impression (see Stephen C. Meyer, Marcus Ross, Paul Nelson, and Paul Chien's essay in this volume). Thus, Gould's discussion of "the extreme rarity of transitional forms" does bear on the question of the truth of universal common descent (evolution #5), and critics of evolution in this sense quite legitimately cite him on this point.

Third, in the passage cited, Gould is not in fact discussing "whether the rate of change of species is slow or gradual"; he is discussing "the extreme rarity of transitional forms in the fossil record." Because Gould accepts universal common descent and because he wants (as much as possible) to take the fossil evidence at face value, he assumes that a mechanism of morphological change exists that can produce change very rapidly. Gould's belief that morphological change must occur very rapidly constitutes part of his interpretation of why the fossil evidence looks as it does. Others, of course, might choose to interpret that same evidence differently. They might view morphologically disparate groups of organisms (such as the representatives of the new animal phyla that appear in the Cambrian) as having originated separately—that is, without having descended from a common ancestor. Yet the NAS booklet treats critics of evolution (presumably in the fifth sense) as ignorant or confused for failing to recognize "the" distinction between the fact and the mechanism of evolution. In fact, it is the NAS booklet that fails to make important definitional distinctions (between evolution #1–3 and #5—that is, between different senses of evolution that may or may not constitute facts, or between the different senses of evolution that might or might not have occurred).

Interestingly, Gould (one of the fifteen members of the NAS steering committee for its 1999 edition of *Science and Creationism*) also fell into this same rhetorical imprecision by treating the distinction between the fact and theory of evolution as if it constituted a unitary distinction. For example, in "Darwinism Defined: The Difference between Fact and Theory," Gould wrote:

The fact of evolution is as well established as anything in science (as secure as the revolution of the earth about the sun), though absolute certainty has no place in our lexicon. Theories, or statements about the causes of documented evolutionary change, are now in a period of intense debate—a good mark of science in its healthiest state. Facts don't disappear while scientists debate theories. As I wrote in an early issue of this magazine (May 1981),

"Einstein's theory of gravitation replaced Newton's, but apples did not suspend themselves in mid-air pending the outcome."²⁶

Here Gould argues that the occurrence of evolution is a fact and that scientists only theorize about *how* it happened. Yet clearly the sense of evolution that Gould means here to defend, namely, the theory of universal common descent, does not have the same epistemological status as observations of apples falling to the ground. No scientists can directly observe "evolution" (in this sense) occurring. No one can observe the history of life, or the pattern of a branching tree emerging, or the transitions between each of the major groups of organisms. In other places Gould himself speculates that evolution happened too fast for even the fossil record to preserve most of the transitional forms required by the theory of universal common descent.²⁷ Instead, as noted above, the *theory* of universal common descent was (and is) inferred (abductively) from many classes of presently observable phenomena: biogeographical distribution, fossil succession, homology, and the like. These latter phenomena are arguably facts akin to apples falling, but the theory or theories inferred from them are not.

The leadership of the National Association of Biology Teachers (NABT) has also recently adopted this same way of defining the issue in a policy statement about how evolution should be taught. The NABT published its "tenets of science, evolution and biology education" with the following introductory remarks:

Modern biologists constantly study, ponder and deliberate the patterns, mechanisms and pace of evolution, but they do not debate evolution's occurrence. The fossil record and the diversity of extant organisms, combined with modern techniques of molecular biology, taxonomy and geology, provide exhaustive examples and powerful evidence for genetic variation, natural selection, speciation, extinction and other well-established components of current evolutionary theory. Scientific deliberations and modifications of these components clearly demonstrate the vitality and scientific integrity of evolution and the theory that explains it.²⁸

The last phrase, "evolution and the theory that explains it," and the earlier phrase, "biologists . . . do not debate evolution's occurrence," both employ the word *evolution* in an alleged "fact" mode. But precisely which sense of "evolution" is said to be factual rather than theoretical? Like Gould, the NABT statement excludes mechanism (evolution #4 and #6) from the category of fact but lumps most of the other senses of the term

into one mold. Thus, like Gould and the NAS statement, the NABT statement conflates evolution #1–3 with evolution #5. Yes, evolution in the sense of change has occurred, but has enough morphological change occurred to ensure that *all* organisms are related by common ancestry? That question is never seriously addressed, nor can it be, given the equivocal definitions in play.

3. Evolution as an “Unsupervised” and “Impersonal” Process: The Blind Watchmaker Thesis and the National Association of Biology Teachers

The NABT statement equivocates in other, arguably more significant, ways. For example, in 1995 the NABT issued the following statement: “The diversity of life on earth is the outcome of evolution: an unsupervised, impersonal, unpredictable and natural process of temporal descent with genetic modification that is affected by natural selection, chance, historical contingencies and changing environments.”²⁹ Two years later the NABT deleted the words “unsupervised” and “impersonal” after two distinguished scholars, Alvin Plantinga and Huston Smith, wrote the NABT about the inappropriateness of those words: “Science presumably doesn’t address such theological questions, and isn’t equipped to deal with them. How could an empirical inquiry possibly show that God was not guiding and directing evolution?”³⁰

The NABT Board of Directors took up that matter on 8 October 1997, voting unanimously to retain the objectionable wording. Wayne Carley, speaking for the board, said they felt “rather strongly” about keeping the statement unaltered. “We believe it. Evolution is real,” he affirmed.³¹ Carley did not say which meaning of the term *evolution* “is real,” nor did he acknowledge that Plantinga and Huston accept evolution in most of the other senses of the word (#1–4 and/or #5) but were disputing the sixth blind watchmaker thesis as advanced by the NABT. On the last day of the 1997 annual NABT meeting, the board met again and voted to remove the two objectionable words, “unsupervised” and “impersonal,” while maintaining: “The deletion of those two words would not affect the statement’s accurate characterization of evolution, and affirmation of evolution’s importance in science education.”³²

Here again, implicit definitions shift from phrase to phrase. Many scientists, and indeed Plantinga and Huston, would accept “evolution’s importance to science” yet would not accept that scientific evidence has established that an “unsupervised” and “impersonal” (the two deleted

words) mechanism is sufficient to explain the origin of every living system on Earth. But the NABT statement treats these two separate propositions as equivalent.

If the NABT story ended here, some might think that statements affirming evolution in the sixth sense are on their way out. But most prominent evolutionary biologists do not see the blind watchmaker thesis (as defined above) as an optional ideological add-on to neo-Darwinian evolutionary theory. Rather, they see it as a central part of the propositional content of neo-Darwinian theory, as indeed Darwin himself did. Thus, the NABT leadership did not really repudiate its commitment to evolution in the sixth sense. They were merely responding to what Eugenie Scott perceptively called “a communication problem” (a public relations crisis).³³

The NABT’s public relations campaign was soon challenged from the state of Tennessee. Massimo Pigliucci, assistant professor of ecology and evolution at the University of Tennessee, Knoxville, drafted “Defining Evolution: An Open Letter.” His letter was posted on the Darwin Day website as part of a moderated discussion that included contributions from Berkeley law professor (now emeritus) Phillip Johnson and Eugenie Scott of the National Center for Science Education (NCSE). Pigliucci enlisted the signatures of an impressive array of scientists, including Harvard’s Richard Lewontin, to support his rebuff of the NABT for their watering down of “evolution.” The letter urges the NABT to reconsider its change to the classroom definition of evolution in the name of “scientific and educational principles.” It argues that the NABT’s two-word alteration to the definition of evolution “betrays” the “core” of “high ideals” such as “rationalism and open inquiry.” What is this alleged core? The letter states:

Science is based on a fundamental assumption: that the world can be explained by referring only to natural, mechanistic forces. [Phillip] Johnson is quite right in affirming that this is a philosophical position. He is wrong when he suggests that it is an unreasonable and unproven one. In fact, every single experiment conducted by any laboratory in any place on Earth represents a daily test of that assumption. The day in which scientists will be unable to explain natural phenomena without referring to divine intervention or other supernatural forces, we will have a major paradigm shift—of cataclysmic proportions.³⁴

The letter affirms that “all we know so far about the evolutionary process tells us that there is no supervision except for the action of natural selection.” Natural selection, for most evolutionary biologists, is the

primary expression of the “blind watchmaker.” Without foresight it molds existing biological structures into new ones.

Leading sociologist of science Steve Fuller, in a web-posted e-mail, “Why I Won’t Sign the Open Letter,” of 10 February 1998, wrote: “I found the Open Letter from the besieged biology teachers embarrassing. I’m sure there are some nasty things going on in Knoxville, but a petition of the sort circulating here is not the way to handle matters.” Fuller explained his embarrassment in these words: “To describe evolution as ‘impersonal’ and ‘unsupervised’ is indeed ideological, especially when the people behind this petition themselves claim that evolution can neither prove nor disprove the existence of God. It’s agnosticism upfront but atheism through the backdoor.”³⁵

Fuller’s comment identifies the underlying reason for the public relations problem facing the science education establishment. On the one hand, for both public relations and constitutional reasons, public school science teachers and relevant professional societies must maintain ideological and religious neutrality. On the other hand, they are charged to teach a scientific theory that most prominent evolutionary biologists themselves understand to have decidedly metaphysical (indeed, antitheistic) implications.

Caught on the horns of this dilemma, what is a principled science teacher to do? Well, why not acknowledge the dilemma and teach the scientific and philosophical controversies that arise from the origins issue? On the one hand, teachers should explain that what we are calling “mere evolution” (evolution #1–4) is “one of the strongest and most useful scientific theories we have,” to use NAS language. Mere evolution encompasses a vast number of specific cosmological, geological, and biological theories that “incorporate a large body of scientific facts, laws, tested hypotheses, and logical inferences.” On the other hand, teachers should help students understand that a significant minority of scientists dissent on evidential grounds from the theory of universal common descent (evolution #5), and an even greater group dissents from the blind watchmaker hypothesis (evolution #6).³⁶ The equivocal use of the term *evolution* conceals this dissent and prevents open classroom discussion of legitimate scientific controversy and its associated evidential grounds.

Further, science teachers need not ignore the larger philosophical or worldview issues that arise from discussing, for example, the blind watchmaker thesis. The threat of ideological indoctrination does not come from allowing students to ponder the philosophical questions raised by the origins issue. Instead, it comes from force-feeding students a single perspective.

The best way to prevent indoctrination is to teach about the scientific controversies that surround the ideologically charged senses of the term *evolution*. But this can be accomplished only if teachers first define the “E” word precisely, distinguish its many distinct meanings (both uncontroversial and controversial), and allow dissenting scientific opinion about the latter meanings to have a voice in the classroom. Given the interest that such an approach would surely generate among students, one might wonder why informed biology teachers would do anything else.

Notes

1. Maynard M. Metcalf, quoted in *The World's Most Famous Court Trial: Tennessee Evolution Case* (Dayton, Tenn.: Bryan College, 1990), 139. A complete stenographic report of the trial; a reprint of the first edition published in Cincinnati by the National Book Company in 1925.
2. E. J. Larson, *Summer for the Gods: The Scopes Trial and America's Continuing Debate Over Science and Religion* (New York: Basic Books, 1997), 173–75.
3. K. S. Thomson, “The Meanings of Evolution,” *American Scientist* 70 (1982): 529–31.
4. Ibid.
5. P. J. Bowler, “The Changing Meaning of ‘Evolution,’” *Journal of the History of Ideas* 36 (1975): 99. The *Oxford English Dictionary* tipped Bowler to the fact that “since the seventeenth century, non-scientific authors had begun to use ‘evolution’ in a figurative sense, referring to almost any connected sequence of events.” It is not surprising, therefore, that the word *evolution* is now often used across all scientific disciplines and in nonscientific literature as “change over time.”
6. For an accessible introduction to this debate, compare these two sources (appropriate supplemental reading for biology courses): J. Coyne, “Not Black and White,” review of *Melanism: Evolution in Action* by Michael Majerus, *Nature* 396 (1998): 35–36; J. Wells, “Second Thoughts About Peppered Moths,” *Scientist* 13 (1999): 13. Because there is some debate as to whether one should apply the term *microevolution* (in contrast to *macroevolution*) to our evolution meaning #3, we have used the micro/macro “E” terms sparingly. Some prefer to reserve the term *microevolution* for strictly “evolution at or below the species level.” See, for example, D. J. Futuyma, *Evolutionary Biology* (Sunderland, Mass.: Sinauer Associates, 1998), 447. Others find it

helpful to use the term for morphological divergence that generates differences (diversity) distinguishing not just varieties but also species, genera, and families—perhaps even orders, but certainly not the higher taxa disparity (major body plan differences) of classes, phyla, or kingdoms. In any case, *microevolution* is at least a fit term for shifts in gene frequencies within a species.

7. S. C. Meyer, "Of Clues and Causes: A Methodological Interpretation of Origin of Life Studies" (Ph.D. diss., Cambridge University, 1991); S. J. Gould, "Evolution and the Triumph of Homology, or Why History Matters," *American Scientist* 74 (1986): 60–69; W. M. Ho, "Methodological Issues in Evolutionary Theory" (Ph.D. diss., Oxford University, 1965); C. S. Peirce, *Collected Papers*, vols. 1–6, ed. C. Hartshorne and P. Weiss (Cambridge: Cambridge University Press, 1931); C. S. Peirce, "Abduction and Induction," in *The Philosophy of Peirce*, ed. J. Buchler (London: Routledge, 1956), 150–56; E. Sober, *Reconstructing the Past* (Cambridge: MIT Press, 1988).
8. S. C. Meyer, "Laws, Causes, and Facts: Response to Michael Ruse," in *Darwinism: Science or Philosophy?* ed. J. Buell and V. Hearn (Richardson, Tex.: Foundation for Thought and Ethics, 1994), 36.
9. C. Schwabe and G. W. Warr, "A Polyphyletic View of Evolution: The Genetic Potential Hypothesis," *Perspectives in Biology and Medicine* 27 (1984): 465–85; C. Schwabe, "On the Basis of the Studies of the Origins of Life," *Origins of Life* 15 (1985): 213–16; W. G. Inglis, "Evolutionary Waves: Patterns in the Origins of Animal Phyla," *Australian Journal of Zoology* 33 (1985): 153–78; P. Senapathy, *Independent Birth of Organisms* (Madison, Wisc.: Genome Press, 1994); M. S. Gordon, "The Concept of Monophyly: A Speculative Essay," *Biology and Philosophy* 14 (1999): 331–48; W. F. Doolittle, "Phylogenetic Classification and the Universal Tree," *Science* 284 (1999): 2124–28; W. F. Doolittle, "The Nature of the Universal Ancestor and the Evolution of the Proteome," *Current Opinion in Structural Biology* 10 (2000): 355–58; D. W. Thompson, *On Growth and Form* (Reprint; New York: Dover, 1992); P. A. Nelson, *On Common Descent* (Chicago: Evolutionary Monographs, 2004); D. T. Anderson, "Origins and Relationships among the Animal Phyla," *Proceedings of the Linnean Society of New South Wales* 106 (1982): 151–66; J. R. Nursall, "On the Origins of the Major Groups of Animals," *Evolution* 16 (1962): 118–23; G. Webster and B. C. Goodwin, "The Origin of Species: A Structuralist Approach," *Journal of Social and Biological Structures* 5 (1982): 15–47.

10. The primary purpose of definitional analysis is to make explicit how a term is actually used in particular semantic contexts. In our analysis of the “E” word, we are concerned with how prominent biologists and spokespersons for science actually use the term in scientific publications. Accordingly, the goal in evolution #6 is to capture one of the most pervasive meanings of the word as used within leading scientific publications, including biology textbooks. Had our goal been to render the results of a survey given to practicing biologists, the landscape of multiple meanings of evolution beyond evolution #5 would be more nuanced than our evolution #6. For example, a minority of biologists are convinced that divine providence, though beyond scientific detection, renders everything purposeful in nature, even mutation and natural selection. A recent survey shows that only a few biologists who are members of the National Academy of Sciences (an indication of prominence) hold such theistic views (5.5 percent of the NAS biologists surveyed professed belief in a “personal God”). See Edward J. Larson and Larry Witham, “Leading Scientists Still Reject God,” *Nature* 394 (1998): 313.
11. R. Dawkins, *The Blind Watchmaker: Why the Evidence of Evolution Reveals a Universe without Design* (New York: W. W. Norton, 1986), 5.
12. M. Ruse, *Darwinism Defended: A Guide to the Evolution Controversy*, with a foreword by Ernst Mayr (Reading, Mass.: Addison-Wesley, 1982), xi–xii.
13. E. Mayr, “Darwin’s Influence on Modern Thought,” *Scientific American* 283 (2000): 81.
14. G. G. Simpson, *The Meaning of Evolution* (New Haven, Conn.: Yale University Press, 1967), 345.
15. K. Miller and J. Levine, *Biology*, 5th ed. (Upper Saddle River, N.J.: Prentice Hall, 2000), 658. This same textbook also contains these similar statements: “it is important to keep this concept in mind: *Evolution is random and undirected*” (658, emphasis in the original), and “It is important to remember that genetic variation is not controlled or directed toward a goal” (299). Miller and Levine have removed the claim that “evolution works without plan or purpose” in the 2002 edition of their textbook.
16. W. K. Purvis, G. H. Orians, and H. C. Heller, *Life: The Science of Biology*, 4th ed. (Sunderland, Mass.: Sinauer Associates, 1995), 14.
17. D. J. Futuyma, *Evolutionary Biology* (Sunderland, Mass.: Sinauer Associates, 1998), 5.

18. F. J. Ayala, "Darwin's Revolution," in *Creative Evolution?! ed.* J. H. Campbell and J. W. Schopf (Boston: Jones and Barlett, 1994), 5.
19. R. H. Brady, "Dogma and Doubt," *Biological Journal of the Linnean Society* 17 (1982): 79–96; D. Collingridge and M. Eathly, "Science Under Stress—Crisis in Neo-Darwinism," *History and Philosophy of the Life Sciences* 12 (1990): 3–26; G. de Beer, *Homology: An Unsolved Problem* (London: Oxford University Press, 1971); M. Denton, *Evolution: A Theory in Crisis* (Bethesda, Md.: Adler and Adler, 1986); N. Eldredge, *Time Frames: The Evolution of Punctuated Equilibria* (Princeton, N.J.: Princeton University Press, 1985); P. P. Grasse, *Evolution of Living Organisms* (New York: Academic Press, 1977); S. J. Gould, "Is a New and General Theory of Evolution Emerging?" *Paleobiology* 6 (1980): 119–30; M. W. Ho and P. T. Saunders, eds., *Beyond Neo-Darwinism* (London: Academic Press, 1984), ix; Ho, "Methodological Issues"; F. Hoyle and S. Wickramasinghe, *Evolution from Space* (London: J. M. Dent, 1981); S. Kauffman, "New Questions in Genetics and Evolution," *Cladistics* 1 (1985): 1247–65; S. Kauffman, *The Origins of Order: Self-Organization and Selection in Evolution* (Oxford: Oxford University Press, 1993); B. John and G. Miklos, *The Eukaryote Genome in Development* (London: Allen and Unwin, 1988); S. Løvtrup, *Darwinism: The Refutation of Myth* (London: Croom Helm, 1987); R. Lewin, *Bones of Contention* (New York: Simon and Schuster, 1987); P. S. Moorhead and M. M. Chaplain, *Mathematical Challenges to the Neo-Darwinian Interpretation of Evolution* (Philadelphia: Wistar Institute Press, 1967)—see especially the papers and comments from M. Eden, M. Schützenberger, S. M. Ulam, and P. Gavaudan; R. A. Raff and E. C. Raff, eds., *Development as an Evolutionary Process* (New York: Alan R. Liss, 1987), 84; A. Tetry, *A General History of the Sciences*, vol. 4 (London: Thames and Hudson, 1966)—see section on evolution, esp. 446; K. S. Thomson, *Morphogenesis and Evolution* (Oxford: Oxford University Press, 1988); D. B. Wake and G. Roth, eds., *Complex Organismal Functions* (New York: John Wiley, 1989); G. Webster, "The Relations of Natural Forms," in Ho and Saunders, *Beyond Neo-Darwinism*, 193–217; http://www.reviewevolution.com/pressRelease_100Scientists.php.
20. S. Gilbert, J. Opitz, and R. Raff, "Resynthesizing Evolutionary and Developmental Biology," *Developmental Biology* 173 (1996): 361.
21. Kauffman, *Origins of Order*.
22. F. Hoke, "Study Sees Alarming Science Undergrad Dropout Rate," *Scientist* 12, no. 5 (1993): 1.

23. National Academy of Sciences, *Science and Creationism: A View from the National Academy of Sciences* (Washington, D.C.: National Academy Press, 1999). The booklet is also available at <http://www.nap.edu>.
24. *Ibid.*, 28.
25. *Ibid.*
26. S. J. Gould, "Darwinism Defined: The Difference between Fact and Theory," *Discover* (Jan. 1987): 64.
27. S. J. Gould, "Is a New and General Theory of Evolution Emerging?" *Paleobiology* 6 (1980): 127. Gould states: "perhaps, in many cases, the intermediates never existed. . . . I envisage a potential saltational origin for the essential features of key adaptations. Why may we not imagine that gill arch bones of an ancestral agnathan moved forward in one step to surround the mouth and form proto-jaws? Such a change would scarcely establish the *Baupläne* of the gnathostomes. So much more must be altered in the reconstruction of agnathan design—the building of a true shoulder girdle with bony, paired appendages, to say the least. But the discontinuous origin of a proto-jaw might set up new regimes of development and selection that would quickly lead to other, coordinated modifications. Yet Darwin, conflating gradualism with natural selection as he did so often, wrongly proclaimed that any such discontinuity, even for organs (much less taxa) would destroy his theory."
28. "NABT Unveils New Statement on Teaching Evolution," *American Biology Teacher* 58 (Jan. 1996): 61–62. The current NABT statement is at <http://www.nabt.org/Evolution.html>.
29. *Ibid.*
30. Quoted in Eugenie C. Scott, "NABT Statement on Evolution Evolves." Special report of the National Center for Science Education, at <http://www.natcensci.ed.org/nabtart.htm>.
31. Zondervan News Service (13 Oct. 1997). E-mail news from Zondervan Publishing House, <http://www.zondervan.com>, quoting a Religion News Service article, <http://www.religionnews.com>.
32. Scott, "NABT Statement."
33. *Ibid.*
34. <http://fp.bio.utk.edu/darwin/>; <http://fp.bio.utk.edu/darwin/Open%20letter/letterhome.html>.
35. http://vest.gu.se/vest_mail/0605.html.
36. http://www.reviewevolution.com/press/pressRelease_100Scientists.php; *New York Review of Books*, 1 Nov. 2001, 23.