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Should Intelligent Design be Taught in Public School Science Classrooms?

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Abstract A variety of different arguments have been offered for teaching "both sides" of the evolution/ID debate in public schools. This article reviews five of the most common types of arguments advanced by proponents of Intelligent Design and demonstrates how and why they are founded on confusion and misunderstanding. It argues on behalf of teaching evolution, and relegating discussion of ID to philosophy or history courses.

1 Introduction

President G. W. Bush apparently commented to the press as follows.

> Both sides ought to be properly taught … so people can understand what the debate is about… Part of education is to expose people to different schools of thought. … You're asking me whether or not people ought to be exposed to different ideas, and the answer is yes. (Baker and Slevin (2005)

President Bush's comment reflects two deeply held values; he appeals to the value of democracy, and much more subtly, he appeals to the value of Christian faith. Who could deny the importance of diversity of opinion and open debate? Bush is correct that diversity of opinion is rightly part of the democratic process. One ought to be entitled to express and debate one's views in our public forums. This is what it means, of course, to live in a free democratic state.

The downside of democracy, of course, is that occasionally, the majority overrules one's views. The majority of Americans, according to recent polls, believe that either humans have existed in their present state for the entirety of life on earth, or, believe that a supreme being guided the process (Pew Research Center for People and the Press 2006). However, unlike a democracy, science is not an institution where decisions are made by

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mere majority rule. The science classroom should not be a public forum.[1] This is because science is not, strictly speaking, a public forum. Just as in medicine or engineering, so too in the biological sciences; one requires a certain knowledge base and set of skills to become an expert and participate in the community of practitioners. This community decides what ideas get past peer review, based on whether sufficient argument and evidence have been accumulated in their favor. Then the community chooses among the very best theories available, and teaches these to future practitioners.[2] The laying on of hands is not taught in medical school, and prayer is not taught to engineering students as a tool for deciding how best to design a space shuttle. This is not because doctors and engineers have unfounded biases, but because they have a vast body of practical experience and evidence to draw upon. Scientists can most certainly be dogmatic, but above all, they are extremely practical—they look to experience, and they do what works. Thus, not every conceivable hypothesis is given an equal hearing by the scientific community, and not every theory deserves equal time in the classroom. If we wish our high school students to become educated citizens, aware of the most empirically well-supported science, and to compete for jobs in an information-based economy in the global market, they need foundations in those scientific theories that have the strongest empirical support. Evolution is such a theory. Intelligent design is not.[3]

This paper will review five different types of argument Intelligent Design theorists give against evolution, and why they fail.[4] Then, it will conclude with a summary of why evolution should, and intelligent design should not, be taught in public school science classes.

1.1 Five Arguments

There are five kinds of argument that intelligent design proponents give against defenders of evolutionary biology: the demarcation argument, the argument from incredulity, the argument from gee whiz mathematics, the incompleteness argument, and the moral

[1] Some could argue to the contrary that the legal debate over Intelligent Design has turned the science classroom into a public forum. Whether or not this is true, of course, turns upon what is meant by this expression, "public forum." A public forum in the sense intended here is a community that can and moreover should decide, democratically, an accepted position on a question, where credentials for membership in that forum are a matter of either membership in citizenry or elected office. However true it may be that the ID-evolution debate has brought public attention to the question of what counts as science, this paper argues that it is neither the courts, nor the public, ultimately, *but scientists* who *should* determine in specific cases what count as legitimate scientific theory, based on the criteria discussed below. Thus, science is not a public forum in this sense. The legal context of debates over teaching ID in public schools concerns interpretation of the Establishment clause as well as the question of whether the teaching of ID constitutes promotion of religious views by the state. Recent legal decision has concluded that teaching ID constitutes a violation of the separation of church and state (Kitzmiller v. Dover 2005). (Thanks to an anonymous reviewer for their helpful comments on this issue.).

[2] One reviewer notes that the account of science advanced here is very much in keeping with some contributors to McComas (1998). Another suggests that readers may find similar views in the U.S. National Academy of Sciences (2008). Many thanks for these useful references.

[3] Of course, learning science is important in itself, both in terms of the content and learning the practice of critical thinking, whether or not one might use such science to compete for jobs.

[4] It should be noted that these are argument types, not tokens. The aim of this paper is to reply to general kinds of argument, not to each specific argument of the variety of ID proponents, which would require (at the least) a book length manuscript. For an example of a comprehensive and thorough analysis of argument tokens, see Sarkar (2007).

argument. Each of these will be addressed in detail below; but first, a brief summary of each argument is in order.

- The first is the demarcation argument: this holds that there are conditions for something counting as a science, and, evolution fails to meet these conditions. The problems with this argument are several. First, historians, philosophers of science, and scientists themselves have been unable to agree what these conditions are. Every time a demarcation criterion has been proposed, it has been found to have various logical flaws or empirical consequences that most are unwilling to accept. The criteria are either too permissive or too restrictive; we either end up including astrology, or excluding Newton's physics. Philosophers of science have known this for about seventy-five years; thus, whenever the demarcation issue comes up, they either rub their hands with glee or sigh with exhaustion, because they have to give another lecture on the history of such attempts and their various failures. While a comprehensive discussion of the demarcation debate is out of place here, this paper will review some of the difficulties in drawing a hard and fast line between science and pseudoscience. One should not conclude from the fact that we have not been able to draw a hard and fast line between science and pseudoscience that there are not many identifying marks of successful scientific research programs, or that there are no clues that someone is trying to sell you a bill of goods. Just because there are no exact criteria for demarcating bald from hairy men, does not mean that there are no bald men. There are positive criteria for good science, and Intelligent Design does not meet these criteria, as will be discussed further below.
- The second argument is the argument from incredulity. This argument is, roughly: this seems impossible to me; therefore it is impossible. First, it should be immediately apparent that there are serious logical flaws with this argument.[5] Second, answering this argument is one of the most difficult challenges for evolutionists. The argument from incredulity forces evolutionary biologists to make accessible to a general audience the most complex details of their science in a sound bite. Astrophysicists do not have to do this. In part because of this fact, biologists have been forced to become very good at making things look simpler than they are; a byproduct of this is that people often conclude that evolutionary biology is not a very sophisticated science. This is a mistake.
- The third argument is an argument from gee whiz mathematics. The argument is, roughly: There are so and so gazillion bits of information in the universe. It's mathematically impossible that these bits of information could have arisen from random and/or natural processes. Therefore, evolution is impossible. This argument is like the argument from incredulity, but appeals to sophisticated concepts that very few people understand, and so it sounds more compelling. Below will be reviewed some reasons why one should be suspicious of these kinds of arguments. First of all, there's no agreement on a natural measure of information. In other words, it's not clear how we ought to count up the bits. Second, the argument characterizes evolution as a random process, which, strictly speaking, it is not.
- The fourth argument is an incompleteness argument; the "Look, but you can't explain this!" argument. One looks around for controversy, gaps or incompleteness in some science, and then concludes that a science is not very good. The problem with this

[5] That is, it does not follow from the fact that something *seems* difficult or impossible that it is. More detail on this point will be supplied below.

argument is that every science is incomplete.[6] And, any good active research program will involve controversy. Scientists have not finished explaining everything; if they claimed to do so, we should be very suspicious of their claim to doing science.

- The last argument is founded on a moral concern. There is reason to suspect that this concern motivates a good deal of the controversy, and very few public defenders evolutionary biology take the time to address it, but it merits discussion, because it is exactly why many people fear evolutionary biology. There are two aspects of this concern. The first is roughly this. Accepting that humans are evolved organisms requires accepting that we are amoral agents subject to purely biological drives. Teaching our children evolutionary biology will thus cause them to embrace moral nihilism or moral relativism, or, it will take away their foundation of and motivation for behaving morally, since it requires that they have to accept that humans lack free will. The second argument is founded on a very specific theological worry—that accepting Darwin's theory requires denying the literal truth of the creation narrative in the Old Testament. To do so is to remove the possibility of salvation; since, salvation requires belief in all statements of the bible as literal truth. Below it will be argued that that the first argument rests upon serious misunderstandings of Darwin's theory. The second argument is much more difficult to address, without engaging in theological debates. An attempt will be made to address how instructors can respond to these concerns in the classroom.

We may now return to each of these arguments in more detail.

2 The Demarcation Argument

There have been many unsuccessful attempts at making a stark demarcation between science and pseudoscience.[7] Here is one example: scientific hypotheses are to admit all and only observable events and processes. The problem with this criterion is that most of our best science would be excluded by it. Most of the natural sciences admit unobservable entities into their theories. And, if we were to rule out the admission of such entities at the outset, scientists would never have considered the theory of gravity, oxygen, genetics, or atomic chemistry. These theories all posit entities and processes that may have been unobservable at some point, some of which were subsequently observed directly, but most of which are supported by a good deal of indirect observational evidence. Certainly, direct observation is important to science, but it is not the singular criterion marking off science from pseudoscience.

Another noteworthy attempt at demarcation was the view advanced by Karl Popper that all and only scientific theories are falsifiable (Popper 1963). A falsifiable theory is one that could, conceivably, be refuted by observational evidence. Part of the problem with this criterion is that, without further elaboration it becomes too *permissive*. It is conceivable that we might find an astrologist's prediction to turn out to be false; thus, this criterion does not rule out astrology as a science. But, you may say, we know that astrologists are sneaky—they make predictions that are so vague as to be bound to be true (e.g., you may find love in the future). So, suppose we modify the original demarcation criterion to allow

[6] This point is mentioned in McComas (1998), as well as the National Academy of Sciences' statement (2008).

[7] For an excellent overview of some common assumptions about science and how they are misguided, see Woodward and Goodstein (1996).

all and only theories that make *specific, bold* predictions. Here, we run into a further trouble. Deriving specific predictions from some theory requires lots of further information. We do not simply derive a prediction from a set of laws, but we rely upon additional background information about the system to which we are applying these laws (e.g. that there are only so many bodies in some system, that some body has a specific mass, or is experiencing wind resistance of such and such a velocity, or so on.). In other words, the consequences of our predictions are not derived from single theories in isolation, but whole sets of background knowledge (Duhem 1903). For this reason, when a prediction is not borne out, we do not automatically reject our theory, but we must also consider those background assumptions we relied upon to derive the prediction at the outset.

For instance, suppose we lived in the 19th century and wanted to predict the exact positions of the planets. What if our predictions are not exactly right? What if the planets do not move as we predicted? This is exactly the position that Adams and Leverrier were in when they proposed an additional planet to explain deviations in the motions of Uranus from what was predicted by Newton's theory. They did not drop Newton's theory because his predictions were slightly off; rather, they supposed that one of his background assumptions was false; namely, that there were only seven planets. They suggested that there must be more in heaven and earth than was dreamt of in Newton's philosophy, and there was.

The point of this example is that theories are never proven or disproven by a single piece of evidence in isolation. Indeed, scientific theories are never, strictly speaking, proven at all. Proof is the provence of mathematics and logic; empirical science, like any enterprise that makes claims over and above the logically or mathematically necessary, is *fallible* knowledge.[8] The best that we can claim with respect to any empirical claim is that it is highly probable, given the total evidence.[9] Indeed, concern about induction is exactly why Popper originally proposed falsifiability as a demarcation criterion; since theories may not be proven true, he argued, we should instead require that they *could be* proven false. However, falsifiability, without a good deal of qualification, either admits too much, or sets the bar too high (For further discussion, see Kitcher 1982).

While there is so far no stark dividing line between science and pseudo-science, there are several key properties of successful scientific theories. With the exception of the third, none of these are *necessary* conditions for successful science, nor are they individually sufficient; rather, they are jointly sufficient:

- A successful theory has to generate a research program. In other words, it has to suggest new experiments, or, new empirical ways of investigating the world. A good scientific theory never will suggest that the enterprise of inquiry should stop, or that our understanding of how the world works must end at some specified juncture.
- Second, a successful theory will often make connections between, systematize, or unify disparate phenomena in some domain. This is not a necessary criterion for successful science, but it is one feature that many successful scientific theories share. For example, Newton's theory unified celestial and terrestrial mechanics; he showed that the same laws account for the motions of the planets and the motions of apples here on earth (For further discussion, see, e.g., Thagard 1978, or Kitcher 1982).

8 This point is also canvassed in McComas (1998).

9 Though, some, (Popper) deny that even this is possible; Popper claimed that all we may claim is that a hypothesis has not yet been falsified.

– Third, and certainly central, a successful theory has to be in some sense testable. This is not to say that it must be "proven" beyond all possibility of a doubt; nor, as discussed above, should it be immediately rejected upon instances of apparently failed prediction. Rather, one must be able to show how empirical evidence can and should lead one to accept that a given theory is more likely than its competitors. Ideally, not only must one show this, but also the scope, or variety, and amount of evidence in favor of the theory must be greater than for rival theories. Testability is not the same as falsifiability. Testing in the sense intended here includes not only the standard model of experimental testing, where one has a control and experimental group, but also, testing involves the accumulation and relative weighing of evidence, direct and indirect, in support of competing hypotheses. With respect to the very small and the distant past, scientific testing is often like detection in a mystery novel—it involves the accumulation of clues, as it were, that all point in the same direction. Historical sciences like geology, or evolutionary biology, or theories of the origins of the universe cannot utilize the controlled experiment; instead, competing hypotheses are weighted viz. indirect evidence from a variety of relevant sources. (For a thorough discussion, see Cleland 2001; or, Sober 2008).

Evolutionary biology has all three of these features of successful science. Intelligent design has none. Evolutionary biology has been one of the most successful research programs in the 20th century. Some of the most fascinating and important new discoveries in genetics and medicine have developed out of the evolutionary paradigm. Consider the genomes projects. Most people know about the human genome project. However, there was not one, but were many different genome projects going on simultaneously—biologists have mapped the genome of not only humans, but the bacterium, *E. coli*, fruit flies, and mice. Why? Because biologists know that these very different organisms have a good deal in common. Jaques Monod is said to have coined the phrase, "Anything found to be true of *E. Coli* must also be true of the elephant."[10] While Monod's purported claims were surely exaggerations, there are important genetic similarities between different phyla. Evolutionary biology predicts that if we understand the genetics of other species, we will better understand ourselves. This prediction has been borne out. We share many of the very same genes with other species, some of which have some of the very same functions. It is for this reason that scientists at the Huntsman Cancer Institute are studying zebra fish in order to better understand human immune disorders.

Theodosius Dobzhansky, a Russian biologist whose work synthesized genetics and evolutionary biology in the 1940s, once said, "nothing in biology makes sense except in light of evolution" (Dobzhansky 1973). Evolutionary biology unifies the biological sciences. It explains the shared biochemistry, genetic codes, mechanisms of heredity, of organisms as distinct as bacteria and chimpanzees. The successes of evolutionary biology as a research program have been so numerous that it is impossible to summarize them here.[11]

2.1 Incredulity

Intelligent design has none of the marks of a successful research program. Intelligent design proponents' main claim is a negative one: living things cannot be accounted for by known

[10] See Friedmann (2004), for a discussion of the history of this notorious claim, never published; also, see also Zimmer (2008).

[11] For a thorough review, see Futuyma (1998); or, a much shorter account, Charlesworth and Charlesworth 2003.

natural causes. Rather, living things exhibit features that are evidence of an intelligence. Michael Behe (2006) argues that the "irreducible complexity" of cells and biochemical structures requires the action of a designing mind. Dembski (2001) says that the "specified complexity" of things like the human eye must be a product of design, since their existence cannot be explained by chance alone. The appeal to natural selection seems to these critics implausible—that a gradual accumulation of minor variations over time would yield a complex organism, with the capacities for flight, vision, or complex thought, seems impossible. This is a version of the argument from incredulity. Some item—a morphological feature of some organism, or a biochemical folding, is argued to be too difficult or impossible to explain viz. naturalistic causes. Because these traits require many parts to act together in order to achieve their functional goal, natural selection seems an implausible mechanism for the generation of these traits. It seems impossible; therefore, it is impossible.

The only way to address this kind of argument is to discuss the several ways in which biologists propose and test hypotheses about adaptation. What you say may still seem impossible to him or her, but so do many of the claims of quantum physics. Here is an attempt at addressing these arguments.

First, it is important to point out that Darwin's theory is not the theory that chance alone lead to the vastly complex adaptations we see today, in the colloquial sense of chance. Most people mean by chance something that could not be predicted, or, an event that occurred by "random" or unsystematic causes. A process that is random has an equiprobability of occurring in one of several ways, in the way that a fair coin has an equal chance of landing heads or tails. Evolution is not like this. Mutations, the changes in the hereditary material that serve as the "fuel" for evolution, are random *with respect to fitness*; that is, a mutation that improves the relative advantage of one organism versus another in survival and reproduction does not have a higher chance of occurring than one that has zero or deleterious effect. Indeed, most mutations (at the level of molecular changes, i.e., point mutations from A to T or G to C) are neutral with respect to fitness. However, once in a while, a mutation will arise that makes a slight improvement in the organism's fitness, or capacity to survive and reproduce. Thus, a small patch of light sensitive cells might make an organism better suited to evade predators. A cup shaped collection of such cells might give such organisms extra advantage in detecting the direction of the predators' motions. The relative *probability* of survival of organisms endowed with these traits is higher than that of their cohort. Selection is the process whereby those types of individuals with a slight advantage at avoiding predators, accessing food, or acquiring mates, increase their representative type in subsequent generations. Natural selection, repeated over billions of years, can incrementally improve the fit of organisms' to their environment. Natural selection is a "statistical" or "probabilistic" theory—selection coefficients describe probabilistic dispositions, not deterministic ones. Thus, natural selection is a "chance" process not in the sense of "random," but rather in the sense of "probabilistic."[12]

There are two kinds of objections proponents of Intelligent Design advance against such an example. First, they may be incredulous about the first stage—that there are advantageous mutations which occasionally cause individual organisms to better survive and reproduce than their peers. However, anyone who knows something about antibiotic resistance in bacteria will not find this so astounding. In a number of hours, bacteria can develop resistance to any number of obstacles you put in front of them. This is microevolution, in contrast to macroevolutionary change, the origin of two or more taxa from common ancestry. Many Intelligent Design proponents accept microevolution, but deny

[12] For further discussion, see, e.g., Millstein (2006).

that one species may, over time, split into to two or more reproductively isolated new species. They claim that no one has ever observed macroevolutionary change.

First of all, it is important to note that biologists have generated reproductively isolated strains of fruit flies in the lab (Rice and Hostert 1993), and, there are many case studies of speciation in the wild—on plants and animals as diverse from the wasps that burrow into figs and apples to butterflies and various kinds of flowering plants (Coyne and Orr 2004), so it's not strictly true that no one has observed macroevolution. However, Intelligent Design proponents may suggest that even if speciation has been observed, the major transitions in evolution from one phyla to another have not been observed. However, as mentioned before, to take direct observation to be a decisive criterion for science would rule out most of geology, astrophysics, and sub-atomic physics. Many natural processes take a very long time, but scientists are willing to bet that they did occur, if the same causes that they posit to explain very slow geological or astronomical events in the distant past are operating today. This is the principle of uniformitarianism, advocated by Lyell, whose geological work inspired Darwin to observe organisms in interaction with their environments in the present, so as to better understand what causes may have been operating in the past. This method is no different from that of astrophysicists or geologists who study extant patterns in their data and ongoing causal processes in order to better understand the past.

Advocates of Intelligent Design at this point might well ask; but where did you get the first cells? This question is ambiguous. First, if they are asking about the origins of life from a nonliving chemical system, the answer is that this is an active research program, with several different theories at play. One of the most popular theories is that the first life was an "RNA world"—the first self-reproducing molecules were RNA. This area of research is part of biochemistry, not evolutionary biology. While there is certainly no consensus about how life came about, disagreement is not (always) a sign of a science in trouble. If this were the case, then theoretical physicists would be in big trouble. They've been trying to come up with a unified field theory for a rather long time!

If the Intelligent Design advocate's question is instead, how do we arrive at "irreducible" biochemical complexity in the cell, then the following questions must be addressed. First, one must ask, what do you mean by irreducible? Behe says that irreducibly complex mechanisms, like the bacterial flagellum, cannot operate without all their parts in place. Thus, they cannot evolve in a stepwise fashion. There are several problems with such a claim. First, one should be wary any time a claim is made that something cannot happen in the natural world. All sorts of claims have been made to this effect in the history of science; continents cannot move, the atom cannot be split in two, in vitro fertilization is impossible, complex organisms like sheep or dogs cannot be cloned. All such "impossibility" claims turned out to be false. Second, Behe's claim about "irreducibility" is rather vague. Are all systems involving several parts that operate in conjunction "irreducible"? How do we count the parts? Surely there are some biological systems that function perfectly fine without all the parts—we donate everything from our kidneys to our bone marrow and survive. Behe's examples are primarily at the cellular level and below—his cases are blood clotting or the bacterial flagellum. But, evolutionary biologists offer multiple possible pathways for the evolution many such supposedly "irreducibly" complex cellular mechanisms (see, e.g., Thornhill and Ussery 2000; For further discussion, see Sarkar 2007).

There are (roughly) two ways to explain the evolution of what Behe calls "irreducibly" complex mechanisms; the cooption strategy, and the neo-Darwinian approach.[13]

[13] Of course, one could legitimately argue that cooption is neo-Darwinian, insofar as Darwin himself makes reference to such mechanisms.

As mentioned before, biologists have found many of the same hereditary and cellular mechanisms in different species. Sometimes these mechanisms are used for the same function, but sometimes they are used for different things; they are the same tool, with a new use. Such traits have been called "exaptations" (Gould and Vrba 1982).[14] Thus, the pieces of the bacterium flagellum are co-opted from other parts of the cell that were used for other functions in the past. The other neo-Darwinian alternative is that new parts, while not terribly significant at first, gradually become added and integrated into a better functioning system. The important point is this; a trait need not be "perfect" at its initial instantiation—all that is required by natural selection is that it must (in some way) enable its bearer to have some advantage in survival and/or reproduction, relative to its competitors. The challenge that many ID proponents argue cannot be met is that such a thing is possible. But, there are many examples of cases—e.g., a complex eye—where what once seemed impossible—that a less than perfect eye could engender some fitness advantage—turned out to be not only possible, but illustrated in multiple lineages.[15]

2.2 Gee Whiz Mathematics

So far, this paper has answered the demarcation argument and the argument from incredulity. Now, we turn to the "gee whiz mathematics" arguments. These arguments try to establish the impossibility of evolution, via a modus tollens argument.[16] It is a common, simple argument form:

If P, then Q.
Q is false.
Therefore, P is false.

Modus tollens is a deductively valid argument, but validity is not the same as soundness. Here's a version of the argument for the impossibility of evolution:

If there were mindless chance processes governing the universe, then organisms with delicate adaptations could not exist.
Organisms with delicate adaptations do exist.
Therefore, the universe is not governed by mindless chance.

Premise 1 of this argument is false. It is not impossible that organisms with delicate adaptations could exist if the universe were governed by mindless chance processes. And, as explained above, evolution is not a mindless chance process, where by "chance" one means "random."

The gee whiz arguments discussed are either deductive or probabilistic versions of modus tollens argument. They start with a highly idealized (or false) representation of how to model evolution. This model cannot account for this purported result—the complexity of living things, or, the total amount of information in biological systems. In other words, the result is either impossible or highly implausible, if we take the model as true. The reason

[14] For reasons far too complex to go into here, there are difficulties with this notion of exaptation—very briefly, almost every biological trait is in some sense an exaptation, because it's rarely the case that a trait is not in some sense (directly or indirectly) co-opted from another function, at some level of organization.

[15] See Futuyma (1998, pp. 681–685), or a discussion of how the eye has evolved many times in the history of life.

[16] This reconstruction follows that of Sober (2008). For much more detailed discussion of this argument and its problems, please see Sober's excellent text.

these arguments are deceptive is twofold. Either the first part—the model—or, the second part—the result—is characterized in a way that is at worst deceptive, and at best, extremely ambiguous. As already mentioned, there is a problem with determining a natural measure of information. Information theorists don't agree on a natural way of identifying bits of information, so, it becomes awfully hard to count up the bits. The second strategy of Intelligent Design proponents is one that takes evolution to be a search algorithm, which, they say, cannot solve the kind of problems required for evolution to be possible. The reason why these arguments should fail to persuade is first, that evolution is not much like the model they describe, and second, even were evolution like the model they describe, improbability is not the same as impossibility (For further discussion, see Sarkar 2007).

2.3 Incompleteness

The fourth argument mentioned above is the argument from incompleteness. Evolutionary biologists debate a variety of open questions about the pattern and process of evolutionary change. John Beatty (1997) has called many of these debates "relative significance debates." That is, evolutionary biologists disagree with respect to the relative significance of drift and selection in evolution, the relative amount of neutral versus non-neutral genetic variation, and the extent of punctuated versus gradual change in the history of life, among other things. Such controversies are characteristic of an active research program. One way to characterize such debates is to use the language of probabilities. Evolutionary biologists of different stripes may be 60–70% sure that most variation at the molecular level is neutral. Or, they may be 80–90% sure that speciation is largely driven by geographical isolation, followed by drift and adaptation to novel environments. However, one fact that seems fairly well established, about which professional biologists are 99.9999% sure, is the fact of common descent. Is this dogmatism? Have they given up on open, free inquiry? The answer is no; it is important to explain why.

The reason why most biologists are 99.9999% sure that common descent is true has to do with extent, variety of, and independence of evidence for common descent. It is important to understand the distinction among these three factors. Extent of evidence is fairly self-explanatory. Variety of evidence refers to the fact that the evidence for evolution is not all of the same kind; that is, it does not fall into a single class or type of evidence. Laboratory and field studies, genetic sequencing and paleontologists' study of fossils, are different types of inquiry, with different sources of evidence. That these sources of evidence are independent of one another lends even greater credence to evolution; the discovery of fossils is independent of the identification and matching of DNA sequencing. And, each of these sources supports common descent. For instance, observation of similarity of, for example, vertebrate body plans, is independent of evidence for a near universally shared genetic code. Further evidence for common descent sometimes comes from surprising sources—e.g., from medicine or immunology.

2.4 Morality and Evolution

What motivates many Americans to be resistant to evolution?[17] There are (at least) four reasons. The first reason is lack of understanding of evolution, and of natural selection in particular. Many Americans, when asked what natural selection is, will describe it as a

[17] A Gallup Poll conducted in 2008 showed that over 50% of Americans believe either that God created humans in their present form, or somehow guided human evolution (Gallup Poll, May 8–11, 2008b).

Lamarckian process where animals somehow give birth to offspring that are better suited to their environments (Shtulman 2006). Second, knowledge of many scientific theories, and evolution in particular, is not "natural and intuitive," according to some psychologists. More precisely, children tend to be "promiscuous teleologists," ascribing purposes to everything in nature, and, they tend to prefer creationist to evolutionary accounts of the origins of animals and plants (Kelemen 1999, 2003, 2004; Kelemen and DiYanni 2005; Evans 2001). These assumptions and biases developed in childhood can lead children to resist scientific knowledge (Bloom and Weisberg 2007). Moreover, many scientific theories are not marked as certain, in the way in which knowledge of geography or the existence of a historical figure like Napoleon is. Because evolution is so described (one "believes in evolution," whereas one does not "believe in Napoleon," or "believe in Paris"—even if one has never observed either) deference is given to authority in determining the truth of such uncertain, complex ideas (Bloom and Weisberg 2007). When children do not trust scientific authority, the incredulity, "gee whiz," as well as the "look you can't explain this" arguments will have purchase. Third, many Americans believe that it is preferable to teach a variety of theories, presumably on the grounds that it is more in keeping with their values, whether Christian or democratic values, or both.[18] However, as discussed above, the sciences are not a public forum where any and all opinions on any question should be heard and decided upon democratically. There are many active debates in the sciences; these debates are ultimately decided by evidence and argument, not public opinion. Further, some of these debates are of historical interest only. Just as we should not teach that we live in an earth-centered universe in the name of diversity, so too we should not teach intelligent design.

Fourth, and perhaps most importantly, many Americans fear that the consequences of accepting evolutionary theory are morally undesirable (Brem et al. 2002). There are several reasons why this is the case. First, many believe that accepting evolution is tantamount to accepting the view that morality is impossible. By placing humans among the other animals, many feel that evolutionary theory somehow compromises our capacity for morality, either by denying the possibility of free will, or, suggesting that human behavior is inevitably self-interested. It is a common misperception that, according to evolutionary theory, the possibility of morally motivated behavior is impossible. Another sense in which accepting the truth of evolution is perceived as morally corrupting is that, according to some, accepting evolution is tantamount to denying purpose in life, indeed, some contend that it is to make salvation impossible; for it is to deny the literal truth of scripture. How to address these concerns? Salvation is no small matter! How can teachers address in a science classroom what is for many Americans such a deeply personal issue? An attempt will be made to address some, if not all, of these concerns below.

First, what of the purported implications of accepting evolutionary biology concerning morality and freedom of the will? Darwin himself was tortured about the impact of his theory, but not because he thought that it implied *moral nihilism*. In fact, Darwin was quite convinced that humans were distinctive in their capacity to reason and behave with consideration and fairness toward others, and, he believed that this was a *consequence* of our being evolved creatures (see, e.g., his *Descent of Man* 1871; or, more recently, Sober and Wilson 1998). He believed that human beings, among other animals, evolved in a social

[18] In response to the question, "Would you generally favor or oppose teaching creation along with evolution in public schools?" a majority was in favor (roughly 65%) but with respect to replacing evolution curriculum with creation curriculum, a majority was opposed (roughly 51%) (CBS News/New York Times Poll. Nov. 18–21, 2004. N = 885 adults nationwide.).

environment, such that there was selection for altruistic behavior. Social groups that cooperated with one another were more successful than groups that did not. If this view is correct, Darwin's theory does not imply that humans are innately anarchic or competitive. Rather, humans are more likely to be disposed to cooperative and altruistic behavior.

Some think that accepting evolution means that humans have no free will. It's not clear where this idea comes from, but it's certainly not an obvious implication of evolutionary biology.[19] This is not to say that humans have no biologically based behavioral dispositions; mothers who consistently avoided strangling their children in our evolutionary past were more reproductively successful than those that did not, and, to the extent that such a behavioral disposition is heritable, such a trait could have evolved. It is notoriously difficult, however, trying to sort out whether behavioral dispositions have genetic bases. Some biologists in the 19th century thought that there were not only genes for aggression or altruism, but also genes that predisposed people to pray, study mathematics, or become political leaders. Francis Galton collected a book of "men of genius"—prominent citizens in British science and politics, that, (surprise!), were frequently related to one another (Galton 1870). Today, most scientists are much more cautious about attributing behavioral dispositions to genetics. Behavioral dispositions are most likely a product of a complex of genetic and environmental factors; and, as some have argued recently, it is enormously difficult to argue convincingly that such dispositional traits are a product of our evolutionary past (Buller 2005). Accepting that we are evolved organisms does not, or, at least not obviously, require of us that we deny human ability to make choices or accept moral responsibility.

It is important to make clear in the science classroom that evolutionary theory is an empirical, not a normative theory; thus, it does not follow from the fact of evolution that humans ought to act without regard for others. This is a fairly simple logical point; that humans are the endpoint of a long process of descent with modification does not necessarily imply that morality is impossible. Those who draw a direct connection between Darwinism and moral nihilism have seriously misunderstood the claims of the theory. Darwin's central claims were two: all living things are related by common ancestry, and natural selection as the main (but not exclusive) mechanism of descent. But these two theses, *by themselves*, imply nothing whatsoever about how we find meaning in our lives, or how we ought to live. These are empirical, not normative claims; they fully underdetermine moral theory and practice. Nor does acceptance of evolution necessarily require that one give up all forms of religious belief, as many instances of thoughtful historical figures who accepted these two beliefs attest.[20]

However, many are unsatisfied with this logical point. While Darwin's theory does not logically entail a denial of God's existence, it does, they argue, require denial of a certain kind of God—a providential, benevolent, omniscient God, one motivated by love for his creation, and mankind in particular. This seems to be the case for many, since, from a naturalistic perspective, there are no "ends" or "purposes" in nature; the history of life is not aimed toward the evolution of the human species. This gives many religious people pause. Darwin was sensitive to this concern, and corresponded at some length with his

[19] However, it does seem to be the conclusion of many cognitive and neuroscientists. See, for example Wegner (2002), and more recently, Hassin et al. (2006).

[20] A wonderful example is Asa Gray. Some have also argued that there is a domain of faith versus a domain of empirical concern. Questions in the two domains, it is argued, are nonoverlapping—they are different kinds of questions that required different answers, and modes of argument. Gould called this the "two Magisteria" argument (1997).

American advocate and critic, Asa Gray, on exactly this topic. Gray argued that God must have intervened at some points, in some specific ways; Darwin resisted this. He thought that natural selection was sufficient to explain all that needed explaining about the diversification and adaptation of life. For all Darwin knew, he acknowledged, God might have set the laws of nature in motion. However, Darwin thought it problematic that God might then have either directly planned or foreseen the least pleasant aspects of nature—suffering, death, and extinction. He gives the example of the *Ichneumonidae*—a wasp whose larvae feeds within the living bodies of caterpillars—as one that seems particularly challenging for those who would believe in a providential God. Is this kind of suffering inconsistent with God's "beneficence and omnipotence"? Darwin thought it was.[21]

There are several answers that have been attempted in response to such a concern. First, one might argue that despite the appearance of senseless suffering and death in nature, there is a greater purpose. Perhaps this suffering, when viewed from a God's eye view, *sub specie aeternitatis*, is part of a greater good. This is what Kitcher calls "humble providentialism." Kitcher (2007) argues that this modest providentialism "comes at a price," because:

> If you are prepared to treat the divine plan as ultimately mysterious and incomprehensible, then why introduce that thought just here? Why not go further? You might declare that the appearances of common descent are deceptive, that species have been newly created with the vestiges of formerly useful organs and structures… and that the Creator has His own unfathomable reasons for doing this. You might even insist that the earth was made with the appearance of great age… (Kitcher 2007, p. 129)

There are several reasons why believer in a providential God would and should stop here and not go further, however. First of all, to suppose as Kitcher does that we have been deceived by the appearances of an ancient world would be to assume that the benevolent God to whom one is professing devotion is a deceiver. This runs counter to the very belief one is attempting to rescue. Second, to express such doubts—about the appearances of common descent and the age of the earth—is to reject the evidence of one's God-given senses and reason.

Perhaps none of this will persuade; as Kitcher insists, for many, to accept evolution is to accept a "world without providence and purpose" (Kitcher, 2007, p. 156). Yet, that animals suffer and die, due to non-human originated causes (hurricanes, floods, disease), is a fact, independent of whether one accepts evolution. If devotees of a providential God can reconcile this familiar fact with their faith, it's not clear why evolution in particular presents a special challenge. Nineteenth Century natural theologians believed that the very facts of biology—including death and suffering—were *evidences* of God. Malthus's arguments for the providential nature of the culling of human populations by war and disease are an excellent example. The acceptance of the fact of suffering and death in the natural world is not uniquely tied to the acceptance of evolution.

It's not entirely clear why students would or should tie the acceptance of the descent of life by natural selection to a purposeless life. Evolutionary biology has made possible many amazing discoveries in science—important advances in molecular genetics, ecology, conservation biology, and biophysics. All these science draw upon or were made possible by a foundation in an evolutionary view of life. And, an evolved, dynamic planet can be a source of wonder. Darwin spoke of "grandeur in this view of life"—the tangled bank—

[21] See the Darwin Correspondence Project (2007).

with its organisms struggling for survival, was for him a source of awe; it inspired him to learn more, not give up hope. Understanding how and why life evolved can give one a wider, and perhaps even more inspired vision of the diversity and history of life on earth.

Finally, how may one address the concerns of a biblical literalist in a science classroom? While to some extent this is beyond the scope of this paper, perhaps turning to the history of science may be of assistance. Understanding that Darwin's ideas have a history, and a contested one, may play an important role in helping students come to understand how and why the scientific community accepted evolution. Moreover, one can emphasize again that the theory is not a moral, but an empirical theory. Galileo, citing Cardinal Baronius,[22] wrote that the aim of Scripture is to teach people how to get to heaven, not how the heavens go. Galileo argued that two truths cannot contradict one another—he meant that the truth of Scripture was the moral lesson of Christ's example, while the truth of nature was revealed by our sense experience. Whatever the merits of Galileo's argument, it is a useful example. Teachers might explain that just as Galileo was a devoted Catholic and a believer in a sun-centered cosmos, so too many figures in the history of science (and today) were theists and evolutionary biologists. Moreover, they could illustrate how Darwin's theory has been put to use to support a very wide range of religious, moral and political philosophies. From Herbert Spencer to Carnegie, from Proudhon to Kropotkin, Darwin's theory has been championed as providing the decisive empirical foundation for communism and capitalism, Marxism, and Socialism. This variety of schools of thought should lead one to doubt that there is a single political or moral philosophy that either underwrites or follows necessarily from evolutionary thinking. Darwinism—the variety of schools of thought that allied themselves with Darwin—has had a long and contested history exactly because the logical transition from biological states of affairs to moral or political dogma is a slippery one. Understanding that Darwin's ideas have such a history might cause students to question that Darwinism, liberalism, secularism, and moral relativism, are the monolithic unity that so many Americans take them to be.

While all of the above arguments may not be satisfying to a devoted literalist, it does leave the door open for many schools of religious thought. And, this is perhaps the bare minimum required. The science classroom is a context for conveyance of the results of science; one should be sensitive to the variety of religious belief in the United States, but one cannot change the facts of science to suit all possible religious views. Such a policy would result in impossible theatrics in the science classroom. While the recognition of the fallibility of scientific knowledge is important, one should also illustrate how and why scientific theories have become historically successful.

In sum, Intelligent Design should not be taught in the *science* classroom. The reasons are several. Evolution is one of the most successful scientific theories of any century. And, Intelligent Design is not a successful research program with novel predictions or modes of explanation. The arguments for intelligent design are primarily negative ones—they tell us that we cannot explain this, or that science is inadequate to account for that. But this defeatist message is the exact opposite of the spirit of scientific inquiry. A good scientific research program will never suggest that the enterprise of inquiry should stop with the discovery of something complex, or that our understanding of how the world works must end at some specified juncture. The aim of science is to expand our body of knowledge. And, evolutionary biology has been enormously successful at doing just this. If we want our children to become scientifically literate citizens, and if we wish them to compete in

[22] See, e.g., Galileo, "Letter to the Grand Duchess Christina," in Drake, ed. (1957).

the global market, they need to be aware of the main principles of and evidence for evolution.

3 Concluding Comments

So, should Intelligent Design be simply left out of *any possible curriculum*? Not necessarily; while ID does not belong in a science classroom, it could very well belong in a history or philosophy class. If students wish to learn about arguments for Intelligent Design, then they should read Aquinas, Paley, or Gray—some of the most thoughtful advocates of intelligent design in history. These thinkers faced squarely questions of theology, faith, evidence, and knowledge. Such material might be taught in a history, philosophy, or history of religion or science course. Courses in philosophy or history of science or religion would give students skills in critical thinking, and access to the social, cultural, and political context surrounding the development of scientific ideas. There is a place for such discussions, but it is not in the science classroom.[23]

Appendix

Some useful websites for teaching controversial topics

http://serc.carleton.edu/NAGTWorkshops/affective/evolution.html (on teaching evolution)
http://serc.carleton.edu/NAGTWorkshops/affective/sac_video.html (video of workshop on Structured Academic Controversies)
http://tep.uoregon.edu/resources/diversity/methods/methodscontroversialissues.html

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[23] An appendix following gives a list of useful websites for teaching controversial material, and evolution in particular, in the high school and college classroom. Of course, this is a very small sample of a much larger literature that could be surveyed here.

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