THE CASE AGAINST INTELLIGENT DESIGN.

The Faith That Dare Not Speak Its Name

by Jerry Coyne

Post date: 08.11.05
Issue date: 08.22.05

Of Pandas and People
By Percival Davis and Dean H. Kenyon
(Haughton Publishing Company, 170 pp., $24.95)

I.

Exactly eighty years after the Scopes "monkey trial" in Dayton, Tennessee, history is about to repeat itself. In a courtroom in Harrisburg, Pennsylvania in late September, scientists and creationists will square off about whether and how high school students in Dover, Pennsylvania will learn about biological evolution. One would have assumed that these battles were over, but that is to underestimate the fury (and the ingenuity) of creationists scorned.

The Scopes trial of our day--Kitzmiller, et al v. Dover Area School District et al--began innocuously. In the spring of 2004, the district's textbook review committee recommended that a new commercial text replace the outdated biology book. At a school board meeting in June, William Buckingham, the chair of the board's curriculum committee, complained that the proposed replacement book was "laced with Darwinism." After challenging the audience to trace its roots back to a monkey, he suggested that a more suitable textbook would include biblical theories of creation. When asked whether this might offend those of other faiths, Buckingham replied, "This country wasn't founded on Muslim beliefs or evolution. This country was founded on Christianity and our students should be taught as such." Defending his views a week later, Buckingham reportedly pleaded: "Two thousand years ago, someone died on a cross. Can't someone take a stand for him?" And he added: "Nowhere in the Constitution does it call for a separation of church and state."

After a summer of heated but inconclusive wrangling, on October 18, 2004 the Dover school board passed, by a vote of six to three, a resolution that read: "Students will be made aware of gaps/problems in Darwin's theory and of other theories of evolution including, but not limited to, intelligent design. Note: Origins of Life is not taught." A month later, the Dover school district issued a press release revealing how the alternative of "intelligent design" was to be presented. Before starting to teach evolution, biology teachers were to read their ninth-grade students a statement, which included the following language:

The Pennsylvania Academic Standards require students to learn about Darwin's Theory of Evolution and eventually to take a standardized test of which evolution is a part.

Because Darwin's Theory is a theory, it continues to be tested as new evidence is discovered. The Theory is not a fact. Gaps in the Theory exist for which there is no evidence.... Intelligent design is an explanation of the origin of life that differs from Darwin's view. The reference book, *Of Pandas and People*, is available for students to see if they would like to explore this view in an effort to gain an understanding of what intelligent design actually involves. As is true with any theory, students are encouraged to keep an open mind.

The results were dramatic but predictable. Two school board members resigned. All eight science teachers at Dover High School sent a letter to the school superintendent pointing out that "intelligent design is not science. It is not biology. It is not an accepted scientific theory." The biology teachers asked to be excused from reading the statement, claiming that to do so would "knowingly and intentionally misrepresent subject matter or curriculum," a violation of their code of professional standards. And so, in January of this year, all ninth-grade biology classes were visited by the assistant superintendent himself, who read the mandated disclaimer while the teachers and a few students left the room.

Inevitably, the controversy went to the courts. Eleven Dover parents filed suit against the school district and its board of directors, asking that the "intelligent design" policy be rescinded for fostering "excessive entanglement of government and religion, coerced religious instruction, and an endorsement by the state of religion over non-religion and of one religious viewpoint over others." The plaintiffs are represented by the Philadelphia law firm of Pepper Hamilton, the Pennsylvania American Civil Liberties Union, and Americans United for Separation of Church and State; the defendants, by the Thomas More Law Center, a conservative Christian organization in Ann Arbor, Michigan.

hy all the fuss about a seemingly inoffensive statement? Who could possibly object to students "keep[ing] an open mind" and examining a respectable-sounding alternative to evolution? Isn't science about testing theories against each other? The furor makes sense only in light of the tortuous history of creationism in America. Since it arose after World War I, Christianfundamentalist creationism has undergone its own evolution, taking on newer forms after absorbing repeated blows from the courts. "Intelligent design," as I will show, is merely the latest incarnation of the biblical creationism espoused by William Jennings Bryan in

Dayton. Far from a respectable scientific alternative to evolution, it is a clever attempt to sneak religion, cloaked in the guise of science, into the public schools.

The journey from Dayton to Dover was marked by a series of legal verdicts, only one of which, the Scopes trial, favored creationism. In 1925, John Scopes, a high school teacher, was convicted of violating Tennessee's Butler Act, which prohibited the teaching of "any theory that denies the Story of Divine Creation of Man as taught in the Bible, and to teach instead that man has descended from a lower order of animal." The verdict was reversed on a technicality (the judge, instead of the jury, levied the $100 fine), so the case was never appealed. In the wake of Scopes, anti-evolution laws were passed in Mississippi and Arkansas, adding to those passed by Florida and Oklahoma in 1923. Although these laws were rarely enforced, evolution nonetheless quickly disappeared from most high school biology textbooks because publishers feared losing sales in the South, where anti-evolution sentiment ran high.

In 1957, the situation changed. With the launch of Sputnik, Americans awoke to find that a scientifically advanced Soviet Union had beaten the United States into space. This spurred rapid revisions of science textbooks, some emphasizing biological evolution. But the anti-evolution statutes were still in force, and so some teachers using newer books were violating the law. One of these teachers, Susan Epperson, brought suit against the state of Arkansas for violating the Establishment Clause. She won the right to teach evolution, and Epperson v. Arkansas was upheld by the United States Supreme Court in 1968, only a year after Tennessee finally rescinded the Butler Act. Finally it was legal to teach evolution everywhere in America.

The opponents of evolution proceeded to re-think their strategy, deciding that if they could not beat scientists, they would join them. They thus recast themselves as "scientific creationists," proposing an ostensibly non-religious alternative to the theory of evolution that might be acceptable in the classroom. But the empirical claims of scientific creationism--that the Earth is young (6,000 to 10,000 years old), that all species were created suddenly and simultaneously, that mass extinctions were caused by a great worldwide flood--bore a suspicious resemblance to creation stories in the Bible. This strategy was devised largely by Henry Morris, an engineering professor who headed the influential Institute for Creation Research in San Diego and helped to write the textbook Scientific Creationism. The book came in two versions: one purged of religious references for the public schools, the other containing a scriptural appendix explaining that the science came from interpreting the Bible literally.

Scientific creationism proved a bust for two reasons. First, the "science" was ludicrously wrong. We have known for a long time that the Earth is 4.6 billion years old (the 6,000- to 10,000-year claim comes from biblical statements, including toting up the number of "begats") and that species were not created suddenly or simultaneously (not only do most species go extinct, but various groups appear at different times in the fossil record), and we have ample evidence for species' changing over time, as well as for fossils that illustrate large morphological transformations. Most risible was Scientific Creationism's struggle to explain the geological record as a result of a great flood: according to its account, "primitive" organisms such as fish would be found in the lowest layers, while mammals and more "advanced" species appeared in higher layers because they climbed hills and mountains to escape the rising waters. Why dolphins are found in the upper strata with other mammals is one of many facts that this ludicrous fantasy fails to explain.

Scientific creationism also came to grief because its advocates did not adequately hide its religious underpinnings. In 1981, the Arkansas legislature passed an "equal time" bill mandating balanced treatment for "evolution science" and "creation science" in the classroom. The bill was quickly challenged in federal court by a group of religious and scientific plaintiffs led by a Methodist minister named William McLean. The defense was easily outgunned, with Judge William Overton quickly spotting biblical literalism underlying the scientific-creationist arguments. In a landmark opinion (and a masterpiece of legal argument), Overton ruled in McLean v. Arkansas Board of Education that the balanced-treatment act was unconstitutional, asserting that it violated the Establishment Clause in three ways: it lacked a secular legislative purpose, its primary effect was to advance religion, and it fostered excessive government entanglement with religion.

McLean v. Arkansas Board of Education began a string of legal setbacks for scientific creationists. Five years later, in Edwards v. Aguillard, the Supreme Court held that Louisiana's "Creationism Act"--an act that required the teaching of evolution in public schools to be balanced by instruction in "creation science"--was unconstitutional. In the last two decades, federal courts have also used the First Amendment to allow schools to prohibit teaching creationism and to ban school districts from requiring teachers to read evolution disclaimers similar to the one used in Dover, Pennsylvania. To get around these rulings, schools in Alabama, Arkansas, and Georgia began pasting warning stickers in biology textbooks, as if learning about evolution could endanger one's mental health. A recent specimen from Cobb County, Georgia reads: "This textbook contains material on evolution. Evolution is a theory, not a fact, regarding the origin of living things. This material should be approached with an open mind, studied carefully and critically considered."

To laypeople--particularly those unfamiliar with the scientific status of evolution, which is actually a theory and a fact--the phrasing may seem harmless. But in 2005 a federal judge ordered the stickers removed. By singling out evolution as uniquely controversial among scientific theories, the stickers catered to religious biases and thus violated the First Amendment.

But the creationists did not despair. They are animated, after all, by faith. And they are very resourceful. They came up with intelligent design.

II.

Intelligent design, or ID, is the latest pseudoscientific incarnation of religious creationism, cleverly crafted by a new group of enthusiasts to circumvent recent legal restrictions. ID comes in two parts. The first is a simple critique of evolutionary theory, to the effect that Darwinism, as an explanation of the origin, the development, and the diversity of life, is fatally flawed. The second is the assertion that the major features of life are best understood as the result of creation by a supernatural intelligent designer. To understand ID, then, we must first understand modern evolutionary theory (often called "neo-Darwinism" to take into account post-Darwinian modifications).

It is important to realize at the outset that evolution is not "just a theory." It is, again, a theory and a fact. Although non-scientists often equate "theory" with "hunch" or "wild guess," the Oxford English Dictionary defines a scientific theory as "a scheme or system of ideas or statements held as an explanation or account of a group of facts or phenomena; a hypothesis that has been confirmed or established by observation or experiment, and is propounded or accepted as accounting for the known facts." In science, a theory is a convincing explanation for a diversity of data from nature. Thus scientists speak of "atomic theory" and "gravitational theory" as explanations for the properties of matter and the mutual attraction of physical bodies. It makes as little sense to doubt the factuality of evolution as to doubt the factuality of gravity.

Neo-Darwinian theory is not one proposition but several. The first proposition is that populations of organisms have evolved. (Darwin, who used the word "evolved" only once in On the Origin of Species, called this principle "descent with modification.") That is, the species on earth today are the descendants of other species that lived earlier, and the change in these lineages has been gradual, taking thousands to millions of years. Humans, for example, evolved from distinctly different organisms that had smaller brains and probably lived in trees.

The second proposition is that new forms of life are continually generated by the splitting of a single lineage into two or more lineages. This is known as "speciation." About five million years ago, a species of primates split into two distinct lineages: one leading to modern chimpanzees and the other to modern humans. And this ancestral primate itself shared a common ancestor with earlier primates, which in turn shared a common ancestor with other mammals. The earlier ancestor of all mammals shared an even earlier ancestor with reptiles, and so on back to the origin of life. Such successive splitting yields the common metaphor of an evolutionary "tree of life," whose root was the first species to arise and whose twigs are the millions of living species. Any two extant species share a common ancestor, which can in principle be found by tracing that pair of twigs back through the branches to the node where they meet. (Extinction, of course, has pruned some branches--pterodactyls, for example--which represent groups that died off without descendants.) We are more closely related to chimpanzees than to orangutans because our common ancestor with these primates lived five million versus ten million years ago, respectively. (It is important to note that although we share a common ancestor with apes, we did not evolve from living apes, but from apelike species that no longer exist. Similarly, I am related to my cousin, but the ancestors we share are two extinct grandparents.)

The third proposition is that most (though not all) of evolutionary change is probably driven by natural selection: individuals carrying genes that better suit them to the current environment leave more offspring than individuals carrying genes that make them less adapted. Over time, the genetic composition of a population changes, improving its "fit" to the environment. This increasing fit is what gives organisms the appearance of design, although, as we shall see, the "design" can be flawed.

These three propositions were first articulated in 1859 by Darwin in On the Origin of Species, and they have not changed substantially, although they have been refined and supplemented by modern work. But Darwin did not propose these ideas as pure "theory"; he also provided voluminous and convincing evidence for them. The weight of this evidence was so overwhelming that it crushed creationism. Within fifteen years, nearly all biologists, previously adherents of "natural theology," abandoned that view and accepted Darwin's first two propositions. Broad acceptance of natural selection came much later, around 1930.

The overwhelming evidence for evolution can be found in many books (and on many websites). Here I wish to present just a few observations that not only support the neo-Darwinist account, but in so doing refute the alternative theory of creationism--that God specially created organisms and their attributes. Given the similarity between the claims of intelligent design and creationism, it is not surprising that these observations also refute the major tenets of ID.

The fossil record is the most obvious place to search for evidence of evolution. Although the record was sparse in Darwin's time, there were already findings that suggested evolution. The living armadillos of South America bore a striking resemblance to fossil glyptodonts, extinct armored mammals whose fossils occurred in the same area. This suggested that glyptodonts and armadillos shared a common South American ancestry. And the record clearly displayed changes in the forms of life existing over large spans of time, with the deepest and oldest sediments showing marine invertebrates, with fishes appearing much later, and still later amphibians, reptiles, and mammals (along with the persistence of some groups found in earlier stages). This sequence of change was in fact established by creationist geologists long before Darwin, and was often thought to reflect hundreds of acts of divine creation. (This does not exactly comport with the account given in Genesis.)

Yet evolution predicts not just successions of forms, but also genetic lineages from ancestors to descendants. The absence of such transitional series in the fossil record bothered Darwin, who called this "the most obvious and serious objection that can be urged against the theory." (He attributed the missing links, quite reasonably, to the imperfection of the fossil record and the dearth of paleontological collections.) But this objection is no longer valid. Since 1859, paleontologists have turned up Darwin's missing evidence: fossils in profusion, with many sequences showing evolutionary change. In large and small organisms, we can trace, through successive layers of the fossil record, evolutionary changes occurring in lineages. Diatoms get bigger, clamshells get ribbier, horses get larger and toothier, and the human lineage evolves bigger brains, smaller teeth, and increased efficiency at bipedal walking. Moreover, we now have transitional forms connecting major groups of organisms, including fish with tetrapods, dinosaurs with birds, reptiles with mammals, and land mammals with whales. Darwin predicted that such forms would be found, and their discovery vindicated him fully. It also destroys the creationist notion that species were created in their present form and thereafter remained unchanged.

Darwin's second line of evidence comprised the developmental and structural remnants of past ancestry that we find in living species--those features that Stephen Jay Gould called "the senseless signs of history." Examples are numerous. Both birds and toothless anteaters develop tooth buds as embryos, but the teeth are aborted and never erupt; the buds are the remnants of the teeth of the reptilian ancestor of birds and the toothed ancestor of anteaters. The flightless kiwi bird of

New Zealand, familiar from shoe-polish cans, has tiny vestigial wings hidden under its feathers; they are completely useless, but they attest to the fact that kiwis, like all flightless birds, evolved from flying ancestors. Some cave animals, descended from sighted ancestors that invaded caves, have rudimentary eyes that cannot see; the eyes degenerated after they were no longer needed. A creator, especially an intelligent one, would not bestow useless tooth buds, wings, or eyes on large numbers of species.

The human body is also a palimpsest of our ancestry. Our appendix is the vestigial remnant of an intestinal pouch used to ferment the hard-to-digest plant diets of our ancestors. (Orangutans and grazing animals have a large hollow appendix instead of the tiny, wormlike one that we possess.) An appendix is simply a bad thing to have. It is certainly not the product of intelligent design: how many humans died of appendicitis before surgery was invented? And consider also lanugo. Five months after conception, human fetuses grow a thin coat of hair, called lanugo, all over their bodies. It does not seem useful--after all, it is a comfortable 98.6 degrees in utero--and the hair is usually shed shortly before birth. The feature makes sense only as an evolutionary remnant of our primate ancestry; fetal apes also grow such a coat, but they do not shed it.

Recent studies of the human genome provide more evidence that we were not created ex nihilo. Our genome is a veritable Gemisch of non-functional DNA, including many inactive "pseudogenes" that were functional in our ancestors. Why do humans, unlike most mammals, require vitamin C in our diet? Because primates cannot synthesize this essential nutrient from simpler chemicals. Yet we still carry all the genes for synthesizing vitamin C. The gene used for the last step in this pathway was inactivated by mutations forty million years ago, probably because it was unnecessary in fruit-eating primates. But it still sits in our DNA, one of many useless remnants testifying to our evolutionary ancestry.

Darwin's third line of evidence came from biogeography, the study of the geographic distribution of plants and animals. I have already mentioned what Darwin called his "Law of Succession": living organisms in an area most closely resemble fossils found in the same location. This implies that the former evolved from the latter. But Darwin found his strongest evidence on "oceanic islands"--those islands, such as Hawaii and the Galápagos, that were never connected to continents but arose, bereft of life, from beneath the sea.

What struck Darwin about oceanic islands--as opposed to continents or "continental islands" such as Great Britain, which were once connected to continents--was the bizarre nature of their flora and fauna. Oceanic islands are

simply missing or impoverished in many types of animals. Hawaii has no native mammals, reptiles, or amphibians. These animals, as well as freshwater fish, are also missing on St. Helena, a remote oceanic island in the middle of the South Atlantic Ocean. It seems that the intelligent designer forgot to stock oceanic (but not continental!) islands with a sufficient variety of animals. One might respond that this was a strategy of the creator, as those organisms might not survive on islands. But this objection fails, because such animals often do spectacularly well when introduced by humans. Hawaii has been overrun by the introduced cane toad and mongoose, to the detriment of its native fauna.

Strikingly, the native groups that are present on these islands--mainly plants, insects, and birds--are present in profusion, consisting of clusters of numerous similar species. The Galápagos archipelago harbors twenty-three species of land birds, of which fourteen species are finches. Nowhere else in the world will you find an area in which two-thirds of the birds are finches. Hawaii has similar "radiations" of fruit flies and silversword plants, while St. Helena is overloaded with ferns and weevils. Compared with continents or continental islands, then, oceanic islands have unbalanced flora and fauna, lacking many familiar groups but having an over-representation of some species.

Moreover, the animals and the plants inhabiting oceanic islands bear the greatest similarity to species found on the nearest mainland. As Darwin noted when describing the species of the Galápagos, this similarity occurs despite a great difference in habitat, a fact militating against creationism:

> Why should the species which are supposed to have been created in the Galápagos Archipelago, and nowhere else, bear so plainly the stamp of affinity to those created in America? There is nothing in the conditions of life, in the geological nature of the islands, in their height or climate, or in the proportions in which the several classes are associated together, which resembles closely the conditions of the South American coast: in fact there is a considerable dissimilarity in all these respects.

As the final peg in Darwin's biogeographic argument, he noted that the kinds of organisms commonly found on oceanic islands--birds, plants, and insects--are those that can easily get there. Insects and birds can fly to islands (or be blown there by winds), and the seeds of plants can be transported by winds or ocean currents, or in the stomachs of birds. Hawaii may have no native terrestrial mammals, but the islands do harbor one native aquatic mammal, the monk seal, and one native flying mammal, the hoary bat. In a direct challenge to creationists (and now also to advocates of ID), Darwin posed this rhetorical question:

Though terrestrial mammals do not occur on oceanic islands, aerial mammals do occur on almost every island. New Zealand possesses two bats found nowhere else in the world: Norfolk Island, the Viti Archipelago, the Bonin Islands, the Caroline and Marianne Archipelagoes, and Mauritius, all possess their peculiar bats. Why, it may be asked, has the supposed creative force produced bats and no other mammals on remote islands?

The answer is that the creative force did not produce bats, or any other creatures, on oceanic islands. All of Darwin's observations about island biogeography point to one explanation: species on islands descend from individuals who successfully colonized from the mainland and subsequently evolved into new species. Only the theory of evolution explains the paucity of mammals, birds, reptiles, amphibians, and freshwater fish on oceanic islands (they cannot get there), the radiation of some groups into many species (the few species that make it to islands find empty niches and speciate profusely), and the resemblance of island species to those from the nearest mainland (an island colonist is most likely to have come from the closest source).

In the last 150 years, immense amounts of new evidence have been collected about biogeography, embryology, and, especially, the fossil record. All of it supports evolution. But support for the idea of natural selection was not so strong, and Darwin had no direct evidence for it. He relied instead on two arguments. The first was logical. If individuals in a population varied genetically (which they do), and some of this variation affected the individual's chance of leaving descendants (which seems likely), then natural selection would work automatically, enriching the population in genes that better adapted individuals to their environment.

The second argument was analogical. Artificial selection used by breeders had wrought immense changes in plants and animals, a fact familiar to everyone. From the ancestral wolf, humans selected forms as diverse as Chihuahuas, St. Bernards, poodles, and bulldogs. Starting with wild cabbage, breeders produced domestic cabbage, broccoli, kohlrabi, kale, cauliflower, and Brussels sprouts. Artificial selection is nearly identical to natural selection, except that humans rather than the environment determine which variants leave offspring. And if artificial selection can produce such a diversity of domesticated plants and animals in a thousand-odd years, natural selection could obviously do much more over millions of years.

But we no longer need to buttress natural selection solely with analogy and logic. Biologists have now observed hundreds of cases of natural selection, beginning with the well-known examples of bacterial resistance to antibiotics, insect resistance to DDT, and HIV resistance to antiviral drugs. Natural selection

accounts for the resistance of fish and mice to predators by making them more camouflaged, and for the adaptation of plants to toxic minerals in the soil. (A long list of examples may be found in Natural Selection in the Wild, by John Endler.) Moreover, the strength of selection observed in the wild, when extrapolated over long periods, is more than adequate to explain the diversification of life on Earth.

Since 1859, Darwin's theories have been expanded, and we now know that some evolutionary change can be caused by forces other than natural selection. For example, random and non-adaptive changes in the frequencies of different genetic variants--the genetic equivalent of coin-tossing--have produced evolutionary changes in DNA sequences. Yet selection is still the only known evolutionary force that can produce the fit between organism and environment (or between organism and organism) that makes nature seem "designed." As the geneticist Theodosius Dobzhansky remarked, "Nothing in biology makes sense except in the light of evolution."

And so evolution has graduated from theory to fact. We know that species on earth today descended from earlier, different species, and that every pair of species had a common ancestor that existed in the past. Most evolutionary change in the features of organisms, moreover, is almost certainly the result of natural selection. But we must also remember that, like all scientific truths, the truth of evolution is provisional: it could conceivably be overturned by future investigations. It is possible (but unlikely!) that we could find human fossils co-existing with dinosaurs, or fossils of birds living alongside those of the earliest invertebrates 600 million years ago. Either observation would sink neo-Darwinism for good.

When applied to evolution, the erroneous distinction between theory and fact shows why tactics such as the Dover disclaimer and the Cobb County textbook sticker are doubly pernicious. To teach that a scientific theory is equivalent to a "guess" or a "hunch" is deeply misleading, and to assert that "evolution is a theory, not a fact" is simply false. And why should evolution, alone among scientific theories, be singled out with the caveat "This material should be approached with an open mind, studied carefully and critically considered"? Why haven't school boards put similar warnings in physics textbooks, noting that gravity and electrons are only theories, not facts, and should be critically considered? After all, nobody has ever seen gravity or an electron. The reason that evolution stands alone is clear: other scientific theories do not offend religious sensibilities.

III.

Given the copious evidence for evolution, it seems unlikely that it will be replaced by an alternative theory. But that is exactly what intelligent-design creationists are demanding. Is there some dramatic new evidence, then, or some insufficiency of neo-Darwinism, that warrants overturning the theory of evolution?

The question is worth asking, but the answer is no. Intelligent design is simply the third attempt of creationists to proselytize our children at the expense of good science and clear thinking. Having failed to ban evolution from schools, and later to get equal classroom time for scientific creationism, they have made a few adjustments designed to sneak Christian cosmogony past the First Amendment. And these adjustments have given ID a popularity never enjoyed by earlier forms of creationism. Even the president of the United States has lent a sympathetic ear: George W. Bush recently told reporters in Texas that intelligent design should be taught in public schools alongside evolution because "part of education is to expose people to different schools of thought." Articles by IDers, or about their "theory," regularly appear in mainstream publications such as The New York Times.

Why have the new image and the new approach been more successful? For a start, IDers have duped many people by further removing God from the picture, or at least hiding him behind the frame. No longer do creationists mention a deity, or even a creator, but simply a neutral-sounding "intelligent designer," as if it were not the same thing. This designer could in principle be Brahma, or the Taoist P'an Ku, or even a space alien; but ID creationists, as will be evident to anybody who attends to all that they say, mean only one entity: the biblical God. Their problem is that invoking this deity in science classes in public schools is unconstitutional. So IDers never refer openly to God, and people unfamiliar with the history of their creationist doctrine might believe that there is a real scientific theory afoot. They use imposing new terms such as "irreducible complexity," which make their arguments seem more sophisticated than those of earlier creationists.

In addition, many IDers have more impressive academic credentials than did earlier scientific creationists, whose talks and antics always bore a whiff of the revival meeting. Unlike scientific creationists, many IDers work at secular institutions rather than at Bible schools. IDers work, speak, and write like trained academics; they do not come off as barely repressed evangelists. Their ranks include Phillip Johnson, the most prominent spokesperson for ID, and a retired professor of law at the University of California, Berkeley; Michael Behe, a professor of biochemistry at Lehigh University; William Dembski, a mathematician-philosopher and the director of the Center for Theology and Science at Southern Baptist Theological Seminary; and Jonathan Wells, who has a doctorate in biology from Berkeley.

All of these proponents, save Johnson, are senior fellows at the Center for Science and Culture (CSC), a division of the Discovery Institute, which is a conservative think tank in Seattle. (Johnson is the "program advisor" to the CSC.) The CSC is the nerve center of the intelligentdesign movement. Its origins are demonstrably religious: as described by the Discovery Institute, the CSC was designed explicitly "to defeat scientific materialism and its destructive moral, cultural, and political legacies" and "to replace materialistic explanations with the theistic understanding that nature and human beings are created by God." Between them, these IDers have published more than a dozen books about intelligent design (Johnson alone has produced eight), which in turn have provoked numerous responses by scientists. Let us examine one of their most influential volumes, the textbook called *Of Pandas and People*. This is the book recommended by the Dover school district as a "reference book" for students interested in learning about intelligent design.

Of Pandas and People is a textbook designed as an antidote to the evolution segment of high school biology classes. It was first published in 1989. By repackaging and updating a subset of traditional young-earth creationist arguments while avoiding taking a stand on any issues that might divide creationists (such as the age of the Earth), it marked the beginning of the modern intelligentdesign movement. By presenting the case for ID, it is supposedly designed to give students a "balanced perspective" on evolution. Although the second edition of *Pandas* is now twelve years old (a third edition, called Design of Life, is in the works), it accurately presents to students the major arguments for ID.

Pandas carefully avoids mentioning God (except under aliases such as "intelligent designer," "master intellect," and so on); but a little digging reveals the book's deep religious roots. One of its authors, Percival Davis, wrote explicitly about his religious beliefs in his book A Case for Creation, co-authored with Wayne Frair: "Truth as God sees it is revealed in the pages of Scripture, and that revelation is therefore more certainly true than any human rationalism. For the creationist, revealed truth controls his view of the universe to at least as great a degree as anything that has been advanced using the scientific method." Its other author, Dean Kenyon, has written approvingly of scientific creationism.

Pandas is published by the Haughton Publishing Company of Dallas, a publisher of agricultural books, but the copyright is held by the Foundation for Thought and Ethics (FTE) in Richardson, Texas. Although the FTE website scrupulously avoids mentioning religion, its articles of incorporation note with stark clarity that its "primary purpose is both religious and educational, which includes, but is not limited to, proclaiming, preaching, teaching, promoting, broadcasting,

disseminating, and otherwise making known the Christian gospel and understanding of the Bible and the light it sheds on the academic and social issues of our day." In a fund-raising letter for the proposed third edition of *Pandas*, Jon Buell, president of the FTE, is equally frank about his goals:

> We will energetically continue to publish and propel these strategic tools in the battle for the minds and hearts of the young.... Yes, most young Americans are exposed to numerous gospel presentations. But the fog of the alien world view deadens their responses. This is why we have to inundate them with a rational, defensible, wellargued Judeo-Christian world view. FTE's carefully-researched books do just that.

Charles Thaxton, the "academic editor" of *Pandas*, is the director of curriculum research for FTE and a fellow of the CSC. In a proto-ID book on the origin of life, Thaxton argued that "Special Creation by a Creator beyond the cosmos is a plausible view of origin science."

Given *Pandas*' pedigree and the affiliations of its authors, it is not surprising that the book is nothing more than disguised creationism. What is surprising is the transparency of this disguise. Despite the efforts of IDers to come up with new anti-Darwinian arguments, *Pandas* turns out to be nothing more than recycled scientific creationism, with most of the old arguments buffed up and proffered as new. (Unlike scientific creationism, however, *Pandas* adopts a studied neutrality toward the facts of astronomy and geology, instead of denying them outright.)

Pandas' discussion of the Earth's age is a prime example of the book's creationist roots, and of its anti-scientific attitude. If the Earth were young--say, the 6,000 to 10,000 years old posited by "young earth" biblical creationists--then evolution would be false. Life simply could not have originated, evolved, and diversified in such a short time. But we now know from several independent and mutually corroborating lines of evidence that the Earth is 4.6 billion years old. All geologists agree on this. So what is *Pandas*' stance on this critical issue? The book merely notes that design proponents "are divided on the issue of the earth's age. Some take the view that the earth's history can be compressed into a framework of thousands of years, while others adhere to the standard old earth chronology." Well, what's the truth? This equivocation is an attempt to paper over a strong disagreement between young-earth creationists and old-earth creationists, both of whom have marched under the banner of ID. It is typical of creationists to exploit disagreements between evolutionists as proof that neo-Darwinism is dead while at the same time hiding their own disagreements from the public.

This equivocation about the fundamental fact of Earth's age does not bode well for the textbook's treatment of the fossil record. Indeed, in this area the authors continue their misrepresentations. Their basic premise is the old creationist argument that organisms appeared simultaneously and have remained largely unchanged ever since. *Pandas* says of the fossil record that "fully formed organisms appear all at once, separated by distinct gaps." That's not exactly true. Different types of organisms appear in a distinct sequence supporting evolution. The first fossils of living organisms, bacteria, appear 3.5 billion years ago, followed two billion years later by algae, the first organisms having true cells with a nucleus containing distinct chromosomes. Then, 600 million years ago, we see the appearance of rudimentary animals with shells, and many soft-bodied marine organisms. Later, in the Cambrian period, about 543 million years ago, a number of groups arose in a relatively short period of time, the so-called "Cambrian explosion." ("Short period" here means geologically short, in this case 10 million to 30 million years). The Cambrian groups include mollusks, starfish, arthropods, worms, and chordates (including vertebrates). And in some cases, such as worms, modern groups do not just spring into being, but increase in complexity over millions of years.

Creationists have always made much of the "Cambrian explosion," and IDers are no exception. The relatively sudden appearance of many groups seems to support the Genesis view of creation. But IDers--and *Pandas*--fail to emphasize several facts. First, the Cambrian explosion was not "sudden"; it took many millions of years. (We still do not understand why many groups originated in even this relatively short time, although it may reflect an artifact: the evolution of easily fossilized hard parts suddenly made organisms capable of being fossilized.) Moreover, the species of the Cambrian are no longer with us, though their descendants are. But over time, nearly every species that ever lived (more than 99 percent of them) has gone extinct without leaving descendants. Finally, many animals and plants do not show up as fossils until well after the Cambrian explosion: bony fishes and land plants first appeared around 440 million years ago, reptiles around 350 million years ago, mammals around 250 million years ago, flowering plants around 210 million years ago, and human ancestors around 5 million years ago. The staggered appearance of groups that become very different over the next 500 million years gives no support to the notion of instantaneously created species that thereafter remain largely unchanged. If this record does reflect the exertions of an intelligent designer, he was apparently dissatisfied with nearly all of his creations, repeatedly destroying them and creating a new set of species that just happened to resemble descendants of those that he had destroyed.

Pandas also makes much of the supposed absence of transitional forms: the "missing" links between major forms of life that, according to evolutionary theory, must have existed as common ancestors. Their absence, claim creationists, is a major embarrassment for evolutionary biology. Phillip Johnson's influential book Darwin on Trial, which appeared in 1993, particularly emphasizes these gaps, which, IDers believe, reflect the designer's creation of major forms ex nihilo. And there are indeed some animals, such as bats, that appear in the fossil record suddenly, without obvious ancestors. Yet in most cases these gaps are certainly due to the imperfection of the fossil record. (Most organisms do not get buried in aquatic sediments, which is a prerequisite for fossilization.) And species that are soft-bodied or have fragile bones, such as bats, degrade before they can fossilize. Paleontologists estimate that we have fossils representing only about one in a thousand of all the species that ever lived.

In its treatment of evolutionary transitions, *Pandas* is again guilty of distortion. Paleontologists have uncovered many transitional forms between major groups, almost more than we have a right to expect. *Pandas* simply ignores--or waves away--these "non-missing links," stating that "we cannot form a smooth, unambiguous transitional series linking, let's say, the first small horse to today's horse, fishes to amphibians, or reptiles to mammals." This is flatly wrong. All three cited transitions (and others) are well documented with fossils. Moreover, the transitional forms appear at exactly the right time in the fossil record: after the ancestral forms already existed, but before the "linked" later group had evolved.

Take one example: the link between early reptiles and later mammals, the so-called mammal-like reptiles. Three hundred fifty million years ago, the world was full of reptiles, but there were no mammals. By 250 million years ago, mammals had appeared on the scene. (Fossil reptiles are easily distinguished from fossil mammals by a complex of skeletal traits including features of the teeth and skull.) Around 275 million years ago, forms appear that are intermediate in skeletal traits between reptiles and mammals, in some cases so intermediate that the animals cannot be unambiguously classified as either reptiles or mammals. These mammal-like reptiles, which become less reptilian and more mammalian with time, are the no-longer-missing links between the two forms, important not only because they have the traits of both forms, but also because they occur at exactly the right time.

One of these traits is worth examining in detail because it is among the finest examples of an evolutionary transition. This trait is the "chewing" hinge where the jaw meets the skull. In early reptiles (and their modern reptilian descendants), the lower jaw comprises several bones, and the hinge is formed by the quadrate bone

of the skull and the articular bone of the jaw. As mammal-like reptiles become more mammalian, these hinge bones become smaller, and ultimately the jaw hinge shifts to a different pair of bones: the dentary (our "jawbone") and the squamosal, another bone of the skull. (The quadrate and articular, much reduced, moved into the middle ear of mammals, forming two of the bones that transmit sounds from the eardrum to the middle ear.) The dentary-squamosal articulation occurs in all modern mammals, the quadrate-articular in modern reptiles; and this difference is often used as the defining feature of these groups.

Like earlier creationist tracts, *Pandas* simply denies that this evolution of the jaw hinge occurred. It asserts that "there is no fossil record of such an amazing process," and further notes that such a migration would be "extraordinary." This echoes the old creationist argument that an adaptive transition from one type of hinge to another by means of natural selection would be impossible: members of a species could not eat during the evolutionary period when their jaws were being unhinged and then rehinged. (The implication is that the intelligent designer must have done this job instantaneously and miraculously.) But we have long known how this transition happened. It was easily accomplished by natural selection. In 1958, Alfred Crompton described the critical fossil: the mammal-like reptile Diarthrognathus broomi. D. broomi has, in fact, a double jaw joint with two hinges--the reptilian one and the mammalian one! Obviously, this animal could chew. What better "missing link" could we find?

It should embarrass IDers that so many of the missing links cited by *Pandas* as evidence for supernatural intervention are no longer missing. Creationists make a serious mistake when using the absence of transitional forms as evidence for an intelligent designer. In the last decade, paleontologists have uncovered a fairly complete evolutionary series of whales, beginning with fully terrestrial animals that became more and more aquatic over time, with their front limbs evolving into flippers and their hind limbs and pelvis gradually reduced to tiny vestiges. When such fossils are found, as they often are, creationists must then punt and change their emphasis to other missing links, continually retreating before the advance of science.

As for other transitional forms, IDers simply dismiss them as aberrant fossils. *Pandas* characterizes Homo erectus and other probable human ancestors as "little more than apes." But this is false. While H. erectus has a skull with large brow ridges and a braincase much smaller than ours, the rest of its skeleton is nearly identical to that of modern humans.The famous fossil Archaeopteryx, a small dinosaur-like creature with teeth and a basically reptilian skeleton but also with wings and feathers, is probably on or closely related to the line of dinosaurs that

evolved into birds. But *Pandas* dismisses this fossil as just an "odd-ball" type, and laments instead the lack of the unfossilizable: "If only we could find a fossil showing scales developing the properties of feathers, or lungs that were intermediate between the very different reptilian and avian lungs, then we would have more to go on." It is again a typical creationist strategy that when skeletons of missing links turn up, creationists ignore them and insist that evidence of intermediacy be sought instead in the soft parts that rarely fossilize. In sum, the treatment of the fossil evidence for evolution in *Pandas* is shoddy and deceptive, and offers no advance over the discredited arguments of scientific creationism.

In contrast to its long treatment and dismissal of the fossil record, *Pandas* barely deals with evidence for evolution from development and vestigial traits. The best it can do is note that vestigial features can have a function, and therefore are not really vestigial. The vestigial pelvic bones and legs of the transitional whale Basilosaurus, which were not connected to the skeleton, may have functioned as a guide for the penis during mating. Such a use, according to the authors of *Pandas*, means that the legs and pelvis "were not vestigial as originally thought." But this argument is wrong: no evolutionist denies that the remnants of ancestral traits can retain some functionality or be co-opted for other uses. The "penis guide" has every bone in the mammalian pelvis and rear leg in reduced form--femur, tibia, fibula, and digits. In Basilosaurus, nearly all of these structures lay within the body wall, and most parts were immobile. Apparently the intelligent designer had a whimsical streak, choosing to construct a sex aid that looked exactly like a degenerate pelvis and set of hind limbs.

And what about the strong evidence for evolution from biogeography? About this *Pandas*, like all creationist books, says nothing. The omission is strategic. It would be very hard for IDers to give plausible reasons why an "intelligent" designer stocked oceanic islands with only a few types of animals and plants--and just those types with the ability to disperse from the nearest mainland. Biogeography has always been the Achilles' heel of creationists, so they just ignore it.

IV.

Although intelligent design rejects much of the evidence for evolution, it still admits that some evolutionary change occurs through natural selection. This change is what *Pandas* calls "microevolution," or "small scale genetic changes, observable in organisms." Such microevolutionary changes include the evolution of antibiotic resistance in bacteria, changes in the proportion of different-colored

moths due to predation by birds, and all changes wrought by artificial selection. But *Pandas* hastens to add that microevolution gives no evidence for the origin of diverse types of organisms, because "these limited changes do not accumulate the way Darwinian evolutionary theory requires in order to produce macro changes. The process that produces macroevolutionary changes [defined here as "large scale changes, leading to new levels of complexity"] must be different from any that geneticists have studied so far."

So, though one can use selection to transform a wolf into either a Chihuahua or a St. Bernard, that is merely microevolution: they are all still dogs. And a DDT-resistant fly is still a fly. *Pandas* thus echoes the ID assertion that natural selection cannot do more than create microevolutionary changes: "It cannot produce new characteristics. It only acts on traits that already exist." But this is specious reasoning. As we have noted, fossils already show that "macro change," as defined by *Pandas*, has occurred in the fossil record (the evolution of fish into amphibians, and so on). And if breeders have not turned a dog into another kind of animal, it is because dog breeding has been going on for only a few thousand years, while the differences between dogs and cats, for example, have evolved over more than ten million years. No principle of evolution dictates that evolutionary changes observed during a human lifetime cannot be extrapolated to much longer periods.

In fact, *Pandas* admits that the fruit flies of Hawaii--a diverse group of more than 300 species--have all evolved from a common ancestor. We now know that this common ancestor lived about 20 million years ago. The species of Hawaiian flies differ in many traits, including size, shape, ecology, color pattern, mating behavior, and so on. One can in fact make a good case that some of the fly species differ more from each other than humans differ from chimps. Why, then, do IDers assert that chimps and humans (whose ancestor lived only 5 million years ago) must have resulted from separate acts of creation by the intelligent designer, while admitting that fruit flies evolved from a common ancestor that lived 20 million years ago? The answer is that humans must at all costs not be lumped in with other species, so as to protect the biblical status of humans as uniquely created in God's image.

ccording to *Pandas*, the theory of "limits to evolution" is a scientific one: "The idea of intelligent design does not preclude the possibility that variation within species occurs, or that new species are formed from existing populations . . . the theory of intelligent design does suggest that there are limits to the amount of variation that natural selection and random change mechanisms can produce." But there is nothing in the theory of intelligent design that tells us how far evolution can go. This "thus far and no further" view of evolution comes not from any

scientific findings of ID; it comes from ID's ancestor, scientific creationism. Scientific Creationism notes that "the creation model . . . recognizes only the kind as the basic created unit, in this case, mankind," and a chart contrasting evolution with the "creation model" says that the former predicts "new kinds appearing," while the latter says "no new kinds appearing."

But what is a "kind"? No creationist has ever defined it, though they are all very sure that humans and apes are different "kinds." In fact, the notion that evolution and creation have operated together, with the latter creating distinct "kinds," was nicely rebutted by Darwin in On the Origin of Species:

> Several eminent naturalists . . . admit that they [evolved species] have been produced by variation, but they refuse to extend the same view to other and very slightly different forms. Nevertheless they do not pretend that they can define, or even conjecture, which are the created forms of life, and which are those produced by secondary laws. They admit variation as a vera causa in one case, they arbitrarily reject it in another, without assigning any distinction in the two cases. The day will come when this will be given as a curious illustration of the blindness of preconceived opinion. These authors seem no more startled at a miraculous act of creation than at an ordinary birth. But do they really believe that at innumerable periods in the earth's history certain elemental atoms have been commanded suddenly to flash into living tissues? Do they believe that at each supposed act of creation one individual or many were produced? Were all the infinitely numerous kinds of animals and plants created as egg or seed, or as full grown? and in the case of mammals, were they created bearing the false marks of nourishment from the mother's womb? Although naturalists very properly demand a full explanation of every difficulty from those who believe in the mutability of species, on their own side they ignore the whole subject of the first appearance of species in what they consider reverent silence.

In fact, the biblical appendix of Scientific Creationism shows that the term "kind" derives from the biblical notion of created kinds:

> The Scriptures are very clear in their teaching that God created all things as He wanted them to be, each with its own particular structure, according to His own sovereign purposes. The account of Genesis 1, for example, indicates that at least ten major categories of organic life were specially created "after his kind." . . . Finally, man "kind" was created as another completely separate category. The phrase "after his kind" occurs ten times in this first chapter of Genesis.

There is thus a clear line of descent from the story of Genesis to the ID notion of evolutionary limits, a line charted by what Darwin called "the blindness of preconceived opinion." Until IDers tell us what the limits to evolution are, how

they can be ascertained, and what evidence supports these limits, this notion cannot be regarded as a genuinely scientific claim.

V.

IDers make one claim that they tout as truly novel, a claim that has become quite popular. It is the idea that organisms show some adaptations that could not be built by natural selection, thus implying the need for a supernatural creative force such as an intelligent designer. These adaptations share a property called "irreducible complexity," a characteristic discussed in *Pandas* but defined more explicitly by Michael Behe in 1996 in his book Darwin's Black Box: The Biochemical Challenge to Evolution: "By irreducibly complex I mean a single system composed of several well-matched, interacting parts that contribute to the basic function, wherein the removal of any one of the parts causes the system to effectively cease functioning."

Many man-made objects show this property: Behe cites the mousetrap, which would not work if even one part were removed, such as the catch, the spring, the base, and so on. *Pandas* mentions a car engine, which will not work if one removes the fan belt, spark plugs, distributor cap, or any of numerous individual parts. A famous example of an irreducibly complex system in the biological realm is the "camera" eye of humans and other vertebrates. The eye has many parts whose individual removal would render the organ useless, including the lens, retina, and optic nerve.

The reason IDers love "irreducibly complex" features of organisms is that natural selection is powerless (or so they claim) to create such features. As Behe notes:

> An irreducibly complex system cannot be produced directly ... by slight, successive modifications of a precursor system, because any precursor to an irreducibly complex system that is missing a part is by definition nonfunctional.... Since natural selection can only choose systems that are already working, then if a biological system cannot be produced gradually it would have to arise as an integrated unit, in one fell swoop, for natural selection to have anything to act on.

"One fell swoop," of course, implies that the feature must have been produced by the miraculous intervention of the intelligent designer.

But this argument for intelligent design has a fatal flaw. We have realized for decades that natural selection can indeed produce systems that, over time, become integrated to the point where they appear to be irreducibly complex. But these

features do not evolve by the sequential addition of parts to a feature that becomes functional only at the end. They evolve by adding, via natural selection, more and more parts into an originally rudimentary but functional system, with these parts sometimes co-opted from other structures. Every step of this process improves the organism's survival, and so is evolutionarily possible via natural selection.

Consider the eye. Creationists have long maintained that it could not have resulted from natural selection, citing a sentence from On the Origin of Species: "To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest degree." But in the next passage, invariably omitted by creationists, Darwin ingeniously answers his own objection:

> Reason tells me, that if numerous gradations from a simple and imperfect eye to one complex and perfect can be shown to exist, each grade being useful to its possessor, as is certainly the case; if further, the eye ever varies and the variations be inherited, as is likewise certainly the case and if such variations should be useful to any animal under changing conditions of life, then the difficulty of believing that a perfect and complex eye could be formed by natural selection, though insuperable by our imagination, should not be considered as subversive of the theory.

Thus our eyes did not suddenly appear as full-fledged camera eyes, but evolved from simpler eyes, having fewer components, in ancestral species. Darwin brilliantly addressed this argument by surveying existing species to see if one could find functional but less complex eyes that not only were useful, but also could be strung together into a hypothetical sequence showing how a camera eye might evolve. If this could be done--and it can--then the argument for irreducible complexity vanishes, for the eyes of existing species are obviously useful, and each step in the hypothetical sequence could thus evolve by natural selection.

A possible sequence of such changes begins with pigmented eye spots (as seen in flatworms), followed by an invagination of the skin to form a cup protecting the eyespot and allowing it to better localize the image (as in limpets), followed by a further narrowing of the cup's opening to produce an improved image (the nautilus), followed by the evolution of a protective transparent cover to protect the opening (ragworms), followed by coagulation of part of the fluid in the eyeball into a lens to help focus the light (abalones), followed by the co-opting of nearby muscles to move the lens and vary the focus (mammals). The evolution of a retina,

an optic nerve, and so on would follow by natural selection. Each step of this transitional "series" confers increased adaptation on its possessor, because it enables the animal to gather more light or to form better images, both of which aid survival. And each step of this process is exemplified by the eye of a different living species. At the end of the sequence we have the camera eye, which seems irreducibly complex. But the complexity is reducible to a series of small, adaptive steps.

Now, we do not know the precise order in which the components of the camera eye evolved--but the point is that the appearance of "irreducible complexity" cannot be an argument against neo-Darwinism if we can document a plausible sequence in which the complexity can arise from a series of adaptive steps. The "irreducible complexity" argument is not, in fact, completely novel. It descends, with modification, from the British theologian William Paley, who in 1802 raised the famous "argument from design" in his book Natural Theology. Paley argued that just as finding a watch on the ground implies a conscious designer (the watchmaker), so finding an equally complex organism implies a cosmic designer (God).

But the eye is not a watch. The human eye, though eminently functional, is imperfect--certainly not the sort of eye an engineer would create from scratch. Its imperfection arises precisely because our eye evolved using whatever components were at hand, or produced by mutation. Since our retina evolved from an everted part of the brain, for example, the nerves and blood vessels that attach to our photoreceptor cells are on the inside rather than the outside of the eye, running over the surface of the retina. Leakage of these blood vessels can occlude vision, a problem that would not occur if the vessels fed the retina from behind. Likewise, to get the nerve impulses from the photocells to the brain, the different nerves must join together and dive back through the eye, forming the optic nerve. This hole in the retina creates a blind spot in the eye, a flaw that again would be avoidable with a priori design. The whole system is like a car in which all the wires to the dashboard hang inside the driver's compartment instead of being tucked safely out of sight. Evolution differs from a priori design because it is constrained to operate by modifying whatever features have evolved previously. Thus evolution yields fitter types that often have flaws. These flaws violate reasonable principles of intelligent design.

IDers tend to concentrate more on biochemistry than on organs such as the eye, citing "irreducibly complex" molecular systems such as the mechanism for blood-clotting and the immune system. Like the eye, these systems supposedly could not have evolved, since removal of any step in these pathways would render the entire

pathway non-functional. (This biochemical complexity is the subject of Behe's book Darwin's Black Box.) Discussing the blood-clotting system in its sixth chapter (partially written by Behe), *Pandas* asserts that "like a car engine, biological systems can only work after they have been assembled by someone who knows what the final result will be." This is nonsense. As we have seen in the case of the eye, biological systems are not useful only at the end of a long evolutionary process, but during every step of that process. And biochemical systems--like all adaptations created by natural selection--are not assembled with foresight. Whatever useful mutations happen to arise get folded into the system.

There is no doubt that many biochemical systems are dauntingly complex. A diagram of the blood-clotting pathway looks like a complicated circuit board, with dozens of proteins interacting with one another to one end: healing a wound. And the system seems irreducibly complex, because without any of several key proteins, the blood would not clot. Yet such biochemical systems evolved in the same way that the eye evolved, by adding parts successively and adaptively to simpler, functioning systems. It is more difficult to trace the evolution of biochemical pathways than of anatomical structures because the ancestral metabolic pathways are no longer present. But biologists are beginning to provide plausible scenarios for how "irreducibly complex" biochemical pathways might have evolved. As expected, these systems involve using bits co-opted from other pathways originally having different functions. (Thus, one of the enzymes in the blood-clotting system also plays a role in digestion and cell division.) In view of our progress in understanding biochemical evolution, it is simply irrational to say that because we do not completely understand how biochemical pathways evolved, we should give up trying and invoke the intelligent designer. If the history of science shows us anything, it is that we get nowhere by labeling our ignorance "God."

VI.

Insofar as intelligent-design theory can be tested scientifically, it has been falsified. Organisms simply do not look as if they had been intelligently designed. Would an intelligent designer create millions of species and then make them go extinct, only to replace them with other species, repeating this process over and over again? Would an intelligent designer produce animals having a mixture of mammalian and reptilian traits, at exactly the time when reptiles are thought to have been evolving into mammals? Why did the designer give tiny, non-functional wings to kiwi birds? Or useless eyes to cave animals? Or a transitory coat of hair to a human fetus? Or an appendix, an injurious organ that just happens to resemble a vestigial version of a digestive pouch in related organisms? Why would the

designer give us a pathway for making vitamin C, but then destroy it by disabling one of its enzymes? Why didn't the intelligent designer stock oceanic islands with reptiles, mammals, amphibians, and freshwater fish, despite the suitability of such islands for these species? And why would he make the flora and fauna on those islands resemble that of the nearest mainland, even when the environments are very different? Why, about a million years ago, would the designer produce creatures that have an apelike cranium perched atop a humanlike skeleton? And why would he then successively replace these creatures with others having an ever-closer resemblance to modern humans?

There are only two answers to these questions: either life resulted not from intelligent design, but from evolution; or the intelligent designer is a cosmic prankster who designed everything to make it look as though it had evolved. Few people, religious or otherwise, will find the second alternative palatable. It is the modern version of the old argument that God put fossils in the rocks to test our faith.

The final blow to the claim that intelligent design is scientific is its proponents' admission that we cannot understand the designer's goals or methods. Behe owns up to this in Darwin's Black Box: "Features that strike us as odd in a design might have been placed there by the designer for a reason--for artistic reasons, to show off, for some as-yetundetectable practical purpose, or for some unguessable reason--or they might not." And, discussing skeletal differences between placental and marsupial mammals, *Pandas* notes:

> Why were not the North American placentals given the same bones? Would an intelligent designer withhold these structures from placentals if they were superior to the placental system? At present we do not know; however, we all recognize that an engineer can choose any of several different engineering solutions to overcome a single design problem. An intelligent designer might reasonably be expected to use a variety (if a limited variety) of design approaches to produce a single engineering solution, also. Even if it is assumed that an intelligent designer did indeed have a good reason for every decision that was made, and for including every trait in each organism, it does not follow that such reasons will be obvious to us.

Well, if we admit that the designer had a number of means and motives, which can be self-contradictory, arbitrary, improvisatory, and "unguessable," then we are left with a theory that cannot be rejected. Every conceivable observation of nature, including those that support evolution, becomes compatible with ID, for the ways of the designer are unfathomable. And a theory that cannot be rejected is not a scientific theory. If IDers want to have a genuinely scientific theory, let them propose a model that can be rigorously tested.

Given its lack of rigor, one might expect that ID theory would not inspire much scientific research. And there is virtually none. Despite the claims of ID to be a program of research, its adherents have published only one refereed paper supporting ID in a scientific journal: a review of ID by Stephen C. Meyer, the director of the Discovery Institute's Center for Science and Culture, which appeared in the Proceedings of the Biological Society of Washington. This paper merely rehashes ID arguments for why natural selection and evolution cannot explain the diversity of life and then asserts that intelligent design is the only alternative. It distorts the evolutionary literature it purports to review, and it neither advances new scientific arguments nor suggests any way that ID better explains patterns in nature. Not surprisingly, the Council of the Biological Society of Washington later disowned the paper because it did "not meet the scientific standards of the Proceedings."

The gold standard for modern scientific achievement is the publication of new results in a peer-reviewed scientific journal. By that standard, IDers have failed miserably. As William Dembski himself noted, "There are good and bad reasons to be skeptical of intelligent design. Perhaps the best reason is that intelligent design has yet to establish itself as a thriving scientific research program." IDers desperately crave scientific respectability, but it is their own theory that prevents them from attaining it. Thus, while IDers demand that evolutionists produce thousands of transitional fossils and hundreds of detailed scenarios about the evolution of biochemical pathways, they put forth no observations supporting the plausibility of a supernatural designer, nor do they show how appeal to such a designer could explain the fossil record, embryology, and biogeography better than neo-Darwinism. Herbert Spencer could have been describing ID when he declared that "those who cavalierly reject the Theory of Evolution as not being adequately supported by facts, seem to forget that their own theory is supported by no facts at all. Like the majority of men who are born to a given belief, they demand the most rigorous proof of any adverse belief, but assume that their own needs none."

Finally, the reliance of ID on supernatural intervention means that the enterprise cannot be seen, strictly speaking, as scientific. In his rejection of scientific creationism in McLean v. Arkansas, Judge Overton described the characteristics of good science:

(1) It is guided by natural law;

(2) It has to be explanatory by reference to natural law;

(3) It is testable against the empirical world;

(4) Its conclusions are tentative, i.e., are not necessarily the final word; and

(5) It is falsifiable.

By invoking the repeated occurrence of supernatural intervention by an intelligent designer to create new species and new traits, ID violates criteria 1 and 2; and in its ultimate reliance on Christian dogma and God, it violates criteria 3, 4, and 5.

In candid moments, usually when writing for or speaking to a religious audience, IDers admit the existence not only of supernatural acts as a part of their theory, but also of Christian supernatural acts. In a foreword to a book on creationism, Johnson wrote: "The intelligent design movement starts with the recognition that 'In the beginning was the Word,' and 'In the beginning God created.' Establishing that point isn't enough, but it is absolutely essential to the rest of the gospel message." And here is Dembski writing in Touchstone, a Christian magazine: "The world is a mirror representing the divine life.... Intelligent design readily embraces the sacramental nature of physical reality. Indeed intelligent design is just the Logos theology of John's Gospel restated in the idiom of information theory." Indeed, in the manuscript draft of the first edition of *Pandas*, the terms "creationism," "creationist," and "creation" are used repeatedly instead of the equivalent ID terms, and "creationism" is defined identically to "intelligent design" in the published version. Nothing gives a clearer indication that one ancestor of this textbook was the Bible.

It is clear, then, that intelligent design did not arise because of some long-standing problems with evolutionary theory, or because new facts have called neoDarwinism into question. ID is here for only one reason--to act as a Trojan horse poised before the public schools: a seemingly secular vessel ready to inject its religious message into the science curriculum. The contents of *Pandas*, and of the other writings of IDers, are simply a cunning pedagogical ploy to circumvent legal restrictions against religious creationism. (With any luck, though, the publicity will backfire. Last month The York Dispatch in Pennsylvania reported that the Foundation for Thought and Ethics, the group that publishes this textbook and others designed to present "a Christian perspective," wanted to intervene in the Dover lawsuit. According to John Buell, the foundation's president, the association of ID with creationism "would make the book radioactive," and his outfit could lose as much as $525,000 in sales.)

ID is part of what Johnson candidly calls the "wedge strategy," a carefully crafted scheme that begins with the adoption of intelligent design as an alternative theory to evolution, after which ID will edge out evolution until it is the only view left, after which it will become full-blown biblical creationism. The ultimate goal is to replace naturalist science with spiritualist thinking, and the method is to hammer the wedge of ID into science at its most vulnerable point: public education. In Johnson's own words:

> So the question is: "How to win?" That's when I began to develop what you now see full-fledged in the "wedge" strategy: "stick with the most important thing," the mechanism and the building up of information. Get the Bible and the Book of Genesis out of the debate because you do not want to raise the so-called Bible-science dichotomy. Phrase the argument in such a way that you can get it heard in the secular academy and in a way that tends to unify the religious dissenters. That means concentrating on, "Do you need a Creator to do the creating, or can nature do it on its own?" and refusing to get sidetracked onto other issues, which people are always trying to do.

Johnson was even more explicit in 1999 in remarks to a conference on "Reclaiming America for Christ." Rob Boston reported Johnson's remarks in Church & State magazine:

> Johnson calls his movement "The Wedge." The objective, he said, is to convince people that Darwinism is inherently atheistic, thus shifting the debate from creationism v. evolution to the existence of God v. the nonexistence of God. From there people are introduced to "the truth" of the Bible and then "the question of sin" and finally "introduced to Jesus."

Other major figures in the ID movement have been equally clear about their religious motivations. Here is Dembski:

> But there are deeper motivations. I think at a fundamental level, in terms of what drives me in this is that I think God's glory is being robbed by these naturalistic approaches to biological evolution, creation, the origin of the world, the origin of biological complexity and diversity. When you are attributing the wonders of nature to these mindless material mechanisms, God's glory is getting robbed.

And here is Jonathan Wells, a member of Reverend Moon's Unification Church:

Father's [Reverend Moon's] words, my studies, and my prayers convinced me that I should devote my life to destroying Darwinism, just as many of my fellow Unificationists had already devoted their lives to destroying Marxism. When Father chose me (along with about a dozen other seminary graduates) to enter a Ph.D. program in 1978, I welcomed the opportunity to prepare myself for battle.

Do these people really believe in intelligent design? There is no reason to think otherwise. They are not lying for their cause, but sincerely hold that life on earth reflects a succession of miracles worked by a supernatural agent. In fact, they view evolutionists as the duplicitous ones. In an interview in The Sacramento Bee in 1991, Johnson proclaimed that "scientists have long known that Darwinism is false. They have adhered to the myth out of self-interest and a zealous desire to put down God." Never mind that many scientists, including evolutionists, are religious.

Given the overwhelming evidence for evolution and the lack of evidence for ID, how can intelligent people hold such views? Is their faith so strong that it blinds them to all evidence? It is a bit more complicated than that. After all, many theologians and religious people accept evolution. The real issues behind intelligent design--and much of creationism--are purpose and morality: specifically, the fear that if evolution is true, then we are no different from other animals, not the special objects of God's creation but a contingent product of natural selection, and so we lack real purpose, and our morality is just the law of the jungle. Tom DeLay furnished a colorful example of this view on the floor of the House of Representatives on June 16, 1999. Explaining the causes of the massacre at Columbine High School, he read a sarcastic letter in a Texas newspaper that suggested that "it couldn't have been because our school systems teach the children that they are nothing but glorified apes who have evolutionized out of some primordial soup of mud."

The notion that naturalism and materialism are the enemies of morality and a sense of human purpose, and that religion is their only ally, is pervasive in the writings of IDers. As Johnson noted, "Once God is culturally determined to be imaginary, then God's morality loses its foundation and withers away." Nancy Pearcey, a senior fellow of the Discovery Institute's Center for Science and Culture, summarizes why evolution disturbs so many Americans:

Why does the public care so passionately about a theory of biology? Because people sense intuitively that there's much more at stake than a scientific theory. They know that when naturalistic evolution is taught in the science classroom, then a naturalistic view of ethics will be taught down the hallway in the history

classroom, the sociology classroom, the family life classroom, and in all areas of the curriculum.

Even some parents in Dover, though opposed to teaching ID in school, worry that learning evolution will erode the Christian values that they are trying to instill in their children.

But the acceptance of evolution need not efface morality or purpose. Evolution is simply a theory about the process and patterns of life's diversification, not a grand philosophical scheme about the meaning of life. Philosophers have argued for years about whether ethics should have a basis in nature. There is certainly no logical connection between evolution and immorality. Nor is there a causal connection: in Europe, religion is far less pervasive than in America, and belief in evolution is more widespread, but somehow the continent remains civilized. Most religious scientists, laymen, and theologians have not found the acceptance of evolution to impede living an upright, meaningful life. And the idea that religion provides the sole foundation for meaning and morality also cannot be right: the world is full of skeptics, agnostics, and atheists who live good and meaningful lives.

Barring a miracle, the Dover Area School District will lose its case. Anyone who bothers to study ID and its evolution from earlier and more overtly religious forms of creationism will find it an unscientific, faith-based theory ultimately resting on the doctrines of fundamentalist Christianity. Its presentation in schools thus violates both the Constitution and the principles of good education. There is no secular reason why evolutionary biology, among all the sciences, should be singled out for a school-mandated disclaimer. But the real losers will be the people of Dover, who will likely be saddled with huge legal bills and either a substantial cut in the school budget or a substantial hike in property taxes. We can also expect that, if they lose, the IDers will re-group and return in a new disguise even less obviously religious. I await the formation of the Right to Teach Problems with Evolution Movement.

IDers have been helped by Americans' continuing doubts about the truth of evolution. According to a Gallup poll taken last year, 45 percent of Americans agree with the statement, "God created human beings pretty much in their present form at one time within the last 10,000 years." Asked if evolution is well supported by evidence, 35 percent of Americans said yes, 35 percent said no, and 29 percent said they lack the knowledge to reply. As a rationalist, I cannot help but believe that the first group would swell were Americans to be thoroughly taught the evidence for evolution, which is rarely done in public high schools. I have seen

creationist students become evolutionists when they learn about biogeography or examine the skulls of mammal-like reptiles. What we need in the schools is not less teaching of evolution but more.

In the end, many Americans may still reject evolution, finding the creationist alternative psychologically more comfortable. But emotion should be distinguished from thought, and a "comfort level" should not affect what is taught in the science classroom. As Judge Overton wrote in his magisterial decision striking down Arkansas Act 590, which mandated equal classroom time for "scientific creationism":

> The application and content of First Amendment principles are not determined by public opinion polls or by a majority vote. Whether the proponents of Act 590 constitute the majority or the minority is quite irrelevant under a constitutional system of government. No group, no matter how large or small, may use the organs of government, of which the public schools are the most conspicuous and influential, to foist its religious beliefs on others.

Jerry Coyne is a professor in the Department of Ecology and Evolution at the University of Chicago.