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CREATIONISM AND INTELLIGENT DESIGN

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■ **Abstract** Creationism, the rejection of evolution in favor of supernatural design, comes in many varieties besides the common young-earth Genesis version. Creationist attacks on science education have been evolving in the last few years through the alliance of different varieties. Instead of calls to teach "creation science," one now finds lobbying for "intelligent design" (ID). Guided by the Discovery Institute's "Wedge strategy," the ID movement aims to overturn evolution and what it sees as a pernicious materialist worldview and to renew a theistic foundation to Western culture, in which human beings are recognized as being created in the image of God. Common ID arguments involving scientific naturalism, "irreducible complexity," "complex specified information," and "icons of evolution," have been thoroughly examined and refuted. Nevertheless, from Kansas to Ohio to the U.S. Congress, ID continues lobbying to teach the controversy, and scientists need to be ready to defend good evolution education.

INTRODUCTION

On October 10, 2002, the American Association for the Advancement of Science (AAAS) Board adopted a resolution that registered its opposition to "so-called 'intelligent design theory,' also known as ID" (1). The resolution was meant to send a message to the Ohio State Board of Education, which seemed poised to include this new form of creationism in the state's science curriculum standards as an alternative to the scientific theory of biological evolution. Noting that "individual scientists and philosophers of science have provided substantive critiques of 'intelligent design,' demonstrating significant conceptual flaws in its formulation, a lack of credible scientific evidence, and misrepresentations of scientific facts," the AAAS Board asked the Association's members to "assist those engaged in overseeing science education policy to understand the nature of science, the content of contemporary evolutionary theory, and the inappropriateness of 'intelligent design theory' as subject matter for science education," and called on affiliated scientific organizations to do the same (1).

The fact that such a resolution was necessary and that such a policy crisis even arose is unfortunate. Until recently, most scientists were unaware of the developments in organized opposition to evolution that led to the current state

of the creation/evolution controversy, and even now few understand the ways and the extent to which the movement has progressed. This essay aims to give a brief overview of these developments, especially as they have occurred in the last decade.

Below, we lay out definitions for some main concepts, and attempt to help overcome common stereotypes about the nature of creationism by providing a typology to distinguish different kinds of antievolutionism. Then we review ways creationist strategies for attacking the teaching of evolution have changed in recent decades, highlighting a couple of recent important battles and identifying new tactics to watch out for. Next we provide details about the ID movement and its Wedge manifesto, which laid out its goals and plans. We provide a brief glossary of some new terminology and the key players in the current public debate. The final section lays out several recommendations for ways scientists can assist the defense of good science education.

DEFINITIONS

In its basic generic sense, creationism refers to any view that rejects evolution in favor of the action of some personal, supernatural creator. Creationism is not limited to Bible-based views because other religions have their own creation accounts that may be in conflict with evolution. For instance, some fundamentalist Hindu sects, such as the Hare Krishnas, reject evolution in favor of their own specific theistic account. Many Native American tribal groups do this as well, as do various Pagan religions.

On the other hand, not all religions are creationist. Many religions and theological traditions accept the scientific understanding of evolution and therefore are not forms of creationism. The Catholic Church and most mainline Protestant denominations, for instance, do not consider evolution to be in conflict with Christian faith, holding that God could have ordained the evolutionary mechanism as the process for creating the biological world.

Most forms of creationism arise in fundamentalist or evangelical religious sects, which tend to hew to a literal or at least a strongly traditional or conservative interpretation of the religion's creation story. The most common form of creationism today rejects not just evolution but much of geology, cosmology, and other sciences, and it affirms a Bible-based view that takes the world and all its life to have been created in a six-day period 6000 to 10,000 years ago. The Institute for Creation Research (ICR), founded by creationist pioneer Henry Morris but now led by his son John Morris, remains the leading and probably the largest organization promoting this view. Answers in Genesis (AiG), led by Ken Ham, now rivals it in size and influence, and there are many other smaller ministries that take the same line.

Another major category of creationists, however, holds that a literal or traditional reading of Genesis does not require this belief in a young earth. They accept that

the earth is billions of years old. This view is commonly referred to as "old-earth creationism" in contrast to the "young-earth creationism" of ICR and AiG. Hugh Ross's Reasons to Believe is one major creationist organization promoting this kind of view. Old-earthers and young-earthers disagree with each other's views as much as they disagree with evolution.

One may find similar factional divisions among creationists regarding other common Genesis-based commitments. Most hold that a catastrophic, universal flood engulfed the earth, killing all life except those that were saved on Noah's ark, whereas others believe the flood was only local or "tranquil." Most now accept microevolution within "kinds" of animals, but hold that such changes are strictly limited and can never form new species, though previous generations of creationists would have found microevolution unacceptable.

The ID Movement was singled out by the AAAS board resolution as the new player in the creation/evolution controversy. It coalesced in the late 1980s and early 1990s under the leadership of Philip Johnson, then a law professor at University of California, Berkeley, and now is unofficially led by members of the Discovery Institute's Center for Science and Culture. The key feature of ID creationism is its attempt to unite various creationist factions against their common enemy under a banner of "mere creation" or "design" by temporarily setting aside internal differences. As Johnson told *Christianity Today*, "People of differing theological views should learn who's close to them, form alliances, and put aside divisive issues 'til later." Aiming to quell the battle between young- and old-earthers to redirect their energies in tandem against evolutionists, he continued, "I say after we've settled the issue of a Creator, we'll have a wonderful time arguing about the age of the Earth" (90). The ID Movement calls its strategy for defeating evolution "the Wedge." Its target is not just evolution, but also the materialist philosophy it believes props up science and is the de facto "established religion" of the West. The organization hopes to affect a renewal in our culture of Judeo-Christian theism, in which man is again understood as created in God's image.

Because of these and other significant differences among forms of creationism, precise terminology is essential, so one should include the specific modifier—young-earth creationism, Hare Krishna creationism, ID creationism, and so on—as appropriate. However, all forms of creationism share certain characteristics—not just the defining characteristics of rejecting evolution in favor of special creation, but also their standard reliance on arguments from ignorance, for example—so one may reasonably use the generic term when the claim is generally applicable.

It is also useful to speak of "antievolutionism," which includes creationism, but is a broader category. The Raëlian Movement, a "scientific religion" that recently has been in the news because of its claim to have cloned a human baby, rejects both evolution and creationism, holding that we were designed by extraterrestrial, but not supernatural, beings. In November 2002, it officially endorsed the ID movement's efforts, announcing that it would pursue legal action to get its own alternative theory taught in the public schools under that heading (70).

CHANGING STRATEGIES

The battle over teaching evolution in public schools shows no signs of cooling. The attack on evolution led by creationists on the Kansas State Board of Education that made international news in 1999 and 2000 was the most high-profile recent case, but dozens of others go unreported in the news media. The National Center for Science Education (NCSE), which tracks and helps defend against antievolutionism, reported that in that same two-year period it became aware of a new problem more than once a week, for a total of 143 different cases at the state or local level from 34 different states (52).

In the 1968 Epperson versus Arkansas case, the U.S. Supreme Court outlawed legislative bans on teaching evolution, such as those that had been in place since the time of the Scopes "Monkey Trial," so creationists have tried other strategies since then. After early attempts in the 1970s to mandate giving equal emphasis to Biblical creation alongside evolution were struck down as unconstitutional, creationists proposed the idea of "scientific creationism," which was supposedly not religious and deserved "balanced treatment" with evolution in the science classroom. Creationist-sponsored bills along these lines were passed in Arkansas and Louisiana in the early 1980s, but again the courts struck them down as unconstitutional. The Louisiana case made its way to the U.S. Supreme Court, which in its 1987 Edwards versus Aguillard decision [Edwards versus Aguillard (1987) 482 U.S. 578] held that creation science was in fact religious because it implied that human beings were created by a supernatural being, so teaching it in public schools violated the separation of church and state.

However, in a dissenting opinion in the case, Justice Scalia wrote that, "The people of Louisiana, including those who are Christian fundamentalists, are quite entitled, as a secular manner, to have whatever scientific evidence there may be against evolution presented in their schools. . ." Creationists have taken this as a possible loophole, and one new strategy has been to try to get their views into the classroom under this rubric of "evidence against evolution." If the Court becomes even more conservative then there is legitimate worry that some future case will create an opening for creationism. The legal idea behind the ID Wedge is to begin with a minimal position that can get into and pry open such a legal crack.

Along similar lines, creationists have begun to lobby to simply teach the controversy about evolution or to get alternative theories taught, purportedly to encourage critical thinking or respect academic freedom. In keeping with the ID strategy, such proposals initially are introduced in vague, seemingly innocuous language and only later is the wedge driven in deeper. Two recent cases illustrate the point.

ID creationists, through Senator Rick Santorum (R-PA), offered an amendment to Bush's 2001 "No Child Left Behind" education bill that would provide an opening for this purpose. Using language drafted by Johnson that echoed his charge that evolution is a philosophical dogma, the proposed amendment noted that the theory of evolution was "controversial" and simply said that science education "should prepare students to distinguish the data or testable theories of science

from philosophical claims that are made in the name of science" (3). With Senator Edward Kennedy's support, after the clause "or religious" was added following "philosophical," it passed without debate as a "Sense of the Senate" resolution. Although the amendment did not mention ID explicitly, in a press release the Discovery Institute trumpeted the resolution as something that would "change the face of the debate over the theories of evolution and intelligent design in America," and opined that "the Darwinian monopoly on public science education, and perhaps on the biological sciences in general, is ending" (3).

In 2002, ID activists appealed to the Santorum amendment during their efforts to get ID theory included when the Ohio State Board of Education was revising its science standards. Santorum published an op-editorial supporting the creationists on the Board: "In order to protect intellectual freedom in the classroom from the dangers of political correctness, I drafted an amendment . . . that emphasizes how students studying controversial issues in science, such as biological evolution, should be allowed to learn about competing interpretations" (75). Making the same claims that creation scientists made in Arkansas and Louisiana, he argued that ID theory was scientific and should therefore be taught: "Proponents of intelligent design are not trying to teach religion via science, but are trying to establish the validity of their theory as a scientific alternative to Darwinism." (75). He made it sound as though support for teaching design was broad and bi-partisan and specifically mentioned Senator Kennedy. In a letter to the editor, Kennedy corrected Santorum's erroneous suggestion that he supported teaching ID, noting that, "Unlike biological evolution, 'intelligent design' is not a genuine scientific theory and, therefore, has no place in the curriculum of our nation's public school science classes." (37).

After months of deliberation, the Ohio State Board of Education adopted standards that did not include ID but did say students should learn "how scientists continue to investigate and critically analyze aspects of evolutionary theory," which the Discovery Institute hailed as a win for ID (92) even though the board unanimously voted to include a last-minute amendment stating that "The intent of this benchmark does not mandate the teaching or testing of intelligent design" (94). It remains to be seen who will win when the standards are implemented.

Even when the creationists fail to get their view included, they work tirelessly to dilute what evolution is taught. For instance, in the 1999 Kansas Board of Education case, when creationists rewrote the science standards they initially tried to include a requirement that ID be taught. When they did not have sufficient votes for that explicit statement, they contented themselves with a line saying, "No evidence or analysis of evidence that contradicts a current science theory will be censured" (60). They then systematically removed standards related to evolution, the Big Bang, and anything having to do with an ancient earth. The Creation Society of Mid-America spearheaded the effort in Kansas, and the Discovery Institute and the local Intelligent Design Network provided speakers, editorial writers, and other support. Fortunately, creationists lost their majority in the next election and the new board voted in January 2001 to return to the original draft of the science standards.

However, creationist activism does not cease. NCSE reports various other kinds of antievolution actions such as attempts to adopt creationist books for classroom or library use or to reject texts that include evolution, to bring in creationist speakers to classrooms or special assemblies, and even to get a zoo to change signs that discussed animal diversity in evolutionary terms. In one amusing case, a school superintendent had teachers glue together pages of an earth science textbook that discussed the big bang because the Genesis account was not also presented (52). NCSE maintains regularly updated information about antievolution flare-ups on its web page.

THE ID WEDGE

The guiding philosophy and strategic plans of the Discovery Institute's Center for Science and Culture (CSC) are laid out in the Wedge document, an internal Discovery Institute manifesto that was leaked and appeared on the Internet in 2000. The CSC was previously named the Center for the Renewal of Science and Culture (CRSC). The Discovery Institute modified the name in 2002. Graphic banners for the CSC have also been modified over the years so that its religious underpinnings are less overt (51). However, the Wedge manifesto makes these explicit, laying out the CSC's fundamental beliefs: "The proposition that human beings are created in the image of God is one of the bedrock principles on which Western civilization was built. Its influence can be detected in most, if not all, of the West's greatest achievements, including representative democracy, human rights, free enterprise, and progress in the arts and sciences. Yet a little over a century ago, this cardinal idea came under wholesale attack by intellectuals drawing on the discoveries of modern science. Debunking the traditional conceptions of both God and man, thinkers such as Charles Darwin, Karl Marx, and Sigmund Freud portrayed humans not as moral and spiritual beings, but as animals or machines who inhabited a universe ruled by purely impersonal forces and whose behavior and very thoughts were dictated by the unbending forces of biology, chemistry, and environment. This materialistic conception of reality eventually infected virtually every area of our culture, from politics and economics to literature and art" (19).

The preamble concludes with a statement of the ID movement's overarching goal: "[It] seeks nothing less than the overthrow of materialism and its cultural legacies," aiming to replace this with a "theistic understanding of nature" (19).

Philosopher Stephen Meyer, one of the earliest leaders of the ID movement who helped define the movement's attack against evolution and naturalism and its revival of what he calls "the God hypothesis" (41), is Director of CSC, and the Wedge document echoes many of the fundamental positions he and Philip Johnson laid out. Meyer's views are critiqued in Reference 65. The CSC's principles and goals for renewing culture on a theistic understanding of nature has brought it significant financial support from the Christian fundamentalist philanthropists who hope ID will help them change the intellectual and political world in this manner (25).

In addition to laying out the movement's fundamental philosophical commitments, the Wedge document also outlined a strategic program of action to achieve its goals. The initial phase was supposed to focus on scientific research, writing, and publication, but literature searches for scientific publications on ID show no progress in this area (25, 27). In Ohio, when lobbying the Board of Education, Meyer and Jonathan Wells, another Discovery Institute Fellow, presented the Board with a bibliography of publications they said contained dissenting viewpoints that challenged evolutionary theory. Given that they were arguing that ID should be included as an alternative, many listeners assumed that the bibliography contained ID publications. Analysis of the bibliography by the NCSE that included a survey of the authors showed that the publications neither supported ID nor undermined evolution, and concluded "the only purpose of the Discovery Institute's Bibliography is to mislead members of the Board and of the public about the status of evolution" (50). The Discovery Institute subsequently added a disclaimer to the online version of their bibliography saying: "The publications are not presented either as support for the theory of intelligent design, or as indicating that the authors cited doubt evolution" (50). Had there been any scientific publications from ID researchers giving evidence of ID, the Discovery Institute surely would have listed them, rather than presenting a misleading list that seriously backfired on them.

Although most leaders of the ID movement are philosophers and lawyers, there is a small group of scientists, including a handful of biologists, who are part of the Wedge and lend their names to the effort. Most notable is Dean Kenyon, a biologist at San Francisco State University, who coauthored (with young-earther Percival Davis) the ID textbook *Of Pandas and People*. The Wedge document mentions Paul Chien, a marine biologist at University of San Francisco, as leading their paleontology research but he has no scientific expertise in that area and admits that his work on the subject is "on the popular level" (25). University of Idaho biologist Scott Minnich has also lent his name to the effort, flying to Ohio to support ID testimony before the Board of Education, for example. All are Fellows of the Discovery Institute, and the Discovery Institute web site explains that Fellows receive research grants up to $50,000 for a year. However, no scientific research appears to be happening. A review of the list of other Discovery Institute Fellows turns up a handful of additional scientists, mostly in other fields, but although the site includes articles by the Fellows, these are mostly popular or op-editorial pieces; there are no preprints of research articles, let alone published scientific articles. Even Michael Behe, a biochemist at Lehigh who is a core leader of the Wedge and whose claim that bio-molecules are "irreducibly complex" is the most touted ID argument, has no scientific publications on ID or any description of scientific research on ID at the Discovery Institute page or at his own university web page.

Despite this complete lack of success in the research phase of the Wedge strategy, ID theorists have forged ahead with the second phase of their plan, "publicity and opinion-making," as well as the third phase, "cultural confrontation and renewal." They sponsor "opinion-maker conferences" and apologetics seminars, publish books and op-editorials, and produce materials for teachers to spread their message.

They have cultivated allies in the media. *The Weekly Standard*, *The Washington Times*, *Books & Culture*, and other conservative newspapers and magazines regularly give them positive press, as does Charles Colson's *BreakPoint* radio show. William F. Buckley showcased ID on his PBS *Firing Line* program several times, including a special debate in which he joined Johnson, Behe, and mathematics writer David Berlinski on the pro-ID team. Berlinski regularly writes in support of ID and is cited as a leader of the movement. He receives funding as a Fellow of the Discovery Institute, as does science writer Forrest Mims. Marvin Olasky, ***Erratum** a University of Texas journalism professor and conservative columnist (famous as the Bush advisor who coined the campaign slogan "compassionate conservatism") also promotes ID, as do various reporters and conservative commentators.

They have also successfully used their political connections not just at the state level of government but also at the federal level, some examples of which have already been mentioned. To give another illustration of the extent of their lobbying effort, on May 10, 2000, the Discovery Institute arranged for several of their key members to give a Congressional Briefing under the title "Scientific Evidence of Intelligent Design and its Implications for Public Policy and Education." The briefing was hosted by Representative Charles Canady (R-FL), Chairman of the House Subcommittee on the Constitution; Senator Sam Brownback (R-KS); House Science Committee members Roscoe Bartlett (R-MD) and Sheila Jackson-Lee (D-TX), Education Committee member Mark Souder (R-IN), and Representative Thomas Petri (R-WI).

There are many other ways in which the ID movement has pushed forward in the opinion-making and cultural renewal phases of its plan. For detailed information about the political aspects of the Wedge strategy, the best source is Reference 25 and the forthcoming Reference 26. A significant point is that lack of scientific support for the ID movement's "theory" has not stood in the way of considerable cultural success in promoting ID as a purported alternative to evolution that should be taught in public schools, and in transforming the terms of this political, if not scientific, debate.

CREATIONIST BUZZ WORDS

This section explains some of the significant new terms. There is a complicated story that could be told for each but space limitations prevent discussion of many problems with the associated arguments. Thus, in each case I will just highlight the main idea and then mention selected, representative conclusions of experts who have evaluated them.

Creation Science

This term was coined by creationists and originally used in the early 1980s as part of a new strategy to overcome the legal prohibition against teaching an explicitly

religious view of origins in the public schools. The idea was that by removing overt reference to the Bible and presenting a relatively vague idea of special creation "scientifically," it could squeeze through a crack in the constitutional wall. ICR founder Henry Morris's book *Scientific Creationism* (47) and *What is Creation Science?* (48) set the model for this view. It had its greatest success in Arkansas when the legislature passed Act 490, a law requiring balanced treatment of creation science and "evolution science." However, the courts did not accept the argument that creation science was really a science and the law was struck down in 1982.

Several books written during that time are noteworthy. Philosopher of science Philip Kitcher's *Abusing Science: The Case Against Creationism* is one of the best critical assessments from the period (38), as is Laurie R. Godfrey's edited collection *Scientists Confront Creationism* (30), which includes essays by Gould, Doolittle, Raup, and others. Arthur Strahler's *Science and Earth History* (82) is an encyclopedic source for rebuttals to a wide range of common creation science arguments and is still a great resource.

Creation science is not a thing of the past. ICR, AiG, and many other creationist organizations continue to promote it. However, because of the long, unsuccessful legal track record under the creation science rubric, antievolution lobbying efforts and activism have in the last few years been eschewing that term in favor of intelligent design theory and retooling their arguments in line with the Wedge strategy.

Design Theory

It is likely that within the next few years creationist activism will complete the switch to using design theory and ID rather than creation science as its banner. By changing names, initially presenting an even more minimal view than creation science, and presenting it as evidence against evolution, creationists' hope is that the courts will not apply the earlier precedents to it. To that end, ID activists will often adamantly deny in public forums that they are promoting creationism even though the religious basis of their view is quite clear in their writings and speeches to supporters, and most of their arguments against evolution are little different than those of creation science. However, because of significant changes in the players and the ways the arguments are presented, older treatments of creation science need to be supplemented.

Philosopher of science Robert T. Pennock's *Tower of Babel: The Evidence Against the New Creationism* (59) criticizes ID creationism and shows its links to creation science. *The New York Review of Books* called it "the best book opposing creationism in all of its guises" (12). *The New York Review of Books* also lauded biologist Kenneth R. Miller's *Finding Darwin's God* (44) for showing "in bracing detail that intelligent design is out of touch with recent research" (12). *Intelligent Design Creationism and Its Critics* (61) is an 800-page sourcebook that includes representative articles by ID theorists together with detailed rebuttals from scientists, theologians, and philosophers of science. A revised edition of *Scientists Confront Creationism* (66) that will deal with ID is slated for publication in 2003.

Icons of Evolution

Creation science and ID are alike in that neither offers positive evidence for their belief that biological organisms were the result of supernatural intervention, but rely entirely on negative arguments against evolution. Their assumption is that design is the only alternative to evolution, and that creation will win by default if they can undermine evolution. Almost all creationist writings rely on trying to poke holes and cast doubt on evolutionary explanations.

The best current example of this common pattern is the ID book *Icons of Evolution* (91) by Wells. As he explained in an interview in *The Cornerstone*, his mission since 1976, when he was a student at Unification Theological Seminary, has been "To defend and articulate Unification theology especially in relation to Darwinian evolution" (85) The Unification creation theory is laid out in Reference 86 and many of Wells's complaints are the same as those given there, and the same as ones made previously by creation scientists. Wells takes issue with 10 common textbook examples: the Miller-Urey experiment, Darwin's tree of life, the homology of the vertebrate limbs, Haeckel's embryos, Archaeopteryx, the peppered moths, Darwin's finches, fruit fly mutations, horse evolution, and human evolution. However, his indictments rarely hold up under close inspection.

For instance, questioning the common textbook photos illustrating the differential camouflaging effect of the light versus dark coloring on tree trunk backgrounds, Wells claims that peppered moths "don't even rest on tree trunks" (91), and that the photos were staged by gluing the moths on. Wells's charges of fraud are now commonly repeated by other creationists when attacking evolution, such as in textbook adoption battles. However, experts in the subject area who have reviewed his charges have consistently dismissed them as misleading and deceptive. There is nothing wrong with gluing moths to trees as part of an experimental trial or to take illustrative photos, given that observations confirm that moths do rest on trunks and other parts of trees (39). Even where there are problems with the classic textbook account, there is ample justification for including the case (72). Peppered moth researcher Bruce Grant minced no words, writing of Wells's claims in *Icons* and elsewhere: "He distorts the picture, but unfortunately he is probably pretty convincing to people who really don't know the primary literature in this field. He uses two tactics. One is the selective omission of relevant work. The other is to scramble together separate points so doubts about one carry over to the other. Basically, he is dishonest" (83).

Other reviewers with a wide range of expertise have been similarly blunt in their assessments. Rudolph Raff reviews Wells's accusations of scientific fraud and censorship and concludes that they are "built on a shaky scaffolding of special pleading and deceptive use of quotations" (71). Jerry Coyne says Wells uses "selective omission to distort a body of literature he pretends to review" (11). Citing many additional cases of misleading omissions of evidence, paleontologists Kevin Padian and Alan Gishlick conclude that *Icons* "can scarcely be considered a work of scholarly integrity" (56). Gishlick elsewhere provides a careful analysis

of Wells's criticisms with special attention to the biology textbooks that Wells criticized (29). The Education Committee of the Society for the Study of Evolution will release a critical assessment of *Icons* for science teachers in 2003.

Irreducible Complexity

In addition to the challenges made in *Icons*, ID theorists claim that certain biological features cannot be explained by evolution even in principle. The most well-know of these is Michael Behe's concept of "irreducible complexity" (IC). Behe's key argument is: "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" (5). He argues that Darwinian evolution cannot produce such systems by gradual modification of precursor systems "because any precursor to an irreducibly complex system that is missing a part is by definition nonfunctional," meaning that the system could only arise as "an integrated unit, in one fell swoop" (5). He goes on to detail a variety of biological systems, including the bacterial flagellum, the blood clotting system, the visual cascade, and vesicular transport, which he claims are irreducibly complex and therefore could not have evolved and must have been designed.

Like Wells, Behe leaves out significant information. Jerry Coyne criticized Behe for his "failure to deal honestly with the evidence for evolution" (10). Tom Cavalier-Smith cited various examples and wonders whether Behe's omissions are "through ignorance or by deliberate intent" (9). Reviewing Behe's arguments, molecular biologist Robert Dorit says that he found the book's premise "that molecular discoveries have plunged a wooden stake through the heart of Darwinian logic" to be "ludicrous" and emphasized six major fallacies in Behe's reasoning (21). Neil Blackstone's assessment in *The Quarterly Review of Biology* is representative of the subsequent assessment of reviewers: "Behe. . .has indulged in some very poor scholarship. He has oversimplified evolutionary theory, made implausible assumptions, committed errors in logic, ignored the relevant literature, and neglected the proper methodology" (7).

Biologist Allen Orr showed how biologists had long considered the apparent problem Behe highlights and had shown how a Darwinian mechanism could indeed produce such systems (54). A similar point was made in References 59 and 80 that typical biochemical systems exhibit redundant and overlapping functions, thus transfer of function is important. Richard Lenski and colleagues (38a) recently published a precise demonstration of how the Darwinian mechanism produces such complex features. Biologist Kenneth Miller was one of the first to point out various problems with Behe's arguments including the absurdity of his suggestion that the designer could have packed all the genes for all the IC systems that would be needed in the history of life into a primordial cell (43), and he has continued to offer regular rebuttals (45, 46) regarding many of Behe's particular examples.

Behe's reaction has been to say that his critics have misunderstood him. However, he recently conceded (6) that a counterexample (59) undermines his argument

as originally formulated. He expressed hope that a revised definition of irreducible complexity in future work would repair the problem, but so far has not provided his promised revision.

Complex Specified Information

In calling for the inclusion of ID in Ohio science standards, Senator Santorum appealed to one of the most common creationist arguments, which says evolution cannot explain the origin of biological information: "[T]here is an increasing body of theoretical and scientific evidence that suggests an alternate theory is possible. Research has shown that the odds that even one small protein molecule has been created by chance is 1 in a billion. Thus, some larger force or intelligence, or what some call agent causation, seems like a viable cause for creating information systems such as the coding of DNA" (75). Some version of this information argument has long been a staple of creationism. Richard Dawkins gives a clear explanation of what is wrong in general with the challenge (13).

The latest version of the information challenge comes from ID theorist William A. Dembski, the most important figure in the ID movement after Johnson and Behe. Dembski, who has collected advanced degrees in mathematics, philosophy, and theology, gives what he claims is a foolproof information-theoretic version of the inference to design. He argues that design can be inferred by a process of elimination through what he calls his "explanatory filter"—if some event cannot be attributed to necessity or to chance then it must have occurred by design. He further argues that what he calls "Specified Complexity" or "Complex Specified Information" (CSI) cannot in principle be produced without intelligence. He claims that biological information (such as Behe's examples of irreducible complexity) is an instance of CSI and so must have been designed.

Among the many flaws in Dembski's argument, his tripartite classification of necessity, chance, and design is neither mutually exclusive nor jointly exhaustive in the ordinary senses of those terms. He gives a technical definition of design as the "set-theoretic complement" of the other two, but this negative definition does not capture the content of the concept. The relevant notion of intentional design that is at issue here is not a syntactic or even a semantic concept but a pragmatic concept that is orthogonal to chance and necessity. His design inference thus fails to get off the ground. Moreover, Dembski's concept of CSI is not clearly defined or applicable to biological information in the manner he claims, and for the illustrative cases he has given, critics have shown that a Darwinian mechanism can discover CSI (59, 62, 63). Similar and additional points are made in References 23, 24, and 87 and in reviews of Dembski's book *The Design Inference* (14).

Philosopher of science Peter Godfrey-Smith finds additional problems: "Dembski's version is one of the least plausible versions of the design argument" (31). Allen Orr (55) dismisses Dembski's updated argument in *No Free Lunch* (16), as does Howard Van Till in a detailed critique (88, 89). Mathematician and computer scientist Jeff Shallit faults *No Free Lunch* for its mathematical difficulties, grandiose claims, equivocation, poor writing, misrepresentation, and poor scholarship (79). Mathematician David Wolpert, an author of the original No Free

Lunch (NFL) theorem to which Dembski appeals, concludes in his review that Dembski's treatment is "fatally informal and imprecise" and points out that the NFL theorems do not apply to the evolution in nature because genomes do not search the same fixed fitness space, as NFL assumes, but coevolve (95).

Much of the debate regarding Dembski's ideas has taken place informally on the Internet. I have restricted citations in this review to published articles but there are several detailed critiques of Dembski's work (and that of other ID theorists) which are posted online that should eventually be published in some professional forum. Elsberry's *Antievolution.org* page on Dembski is the most complete and regularly updated set of references on the give and take between Dembski and his critics (22).

Materialist Worldview/Naturalist Dogma

The claim that teaching evolution amounts to naturalist or materialist dogma is one of the most consistent lines of attack by the new creationists. For instance, in West Virginia, ID activists argued in favor of including ID during revision of the science standards on the grounds that that the standards are not neutral but "promote indoctrination into a naturalistic view" (84). Philip Johnson has systematically promoted this charge, most notably in *Darwin on Trial* (34), which is the pivotal book that grounds the ID movement. He claims that this amounts to the establishment of a religious view (33, 35).

Again, the complaint is not new. Veteran creation science debater Duane Gish used the same attack in the late 1970s: "The reason that most scientists accept evolution is that they prefer to believe a materialistic, naturalistic explanation for the origin of all living things" (28), and it is common for creationists to argue that evolution is a faith. The difference is that Johnson has developed the complaint systematically and made it the centerpiece of the ID attack on evolution. The attack is particularly significant because it challenges the way the courts rejected the claim that creation science is indeed science, namely by reference to how creation science violates basic constraints of scientific methodology, which requires that one appeal only to natural laws rather than to supernatural powers (73).

The answer to the creationists' charge of dogmatic bias lies in the distinction between naturalism/materialism as a metaphysical view and as a methodological constraint. Science need only be committed to the latter, remaining neutral to metaphysical beliefs. Johnson's particular misunderstandings of this distinction are discussed in detail in Reference 58. Theologians also recognize the distinction; Nancey Murphy made a similar criticism of Johnson (49). ID theorists have since turned to attacking methodological naturalism as well, and philosopher of science Michael Ruse, whose testimony about the naturalistic methods of science was critical when he was an expert witness at the Arkansas creationism trial in 1982, defends it against criticisms from philosopher of religion and ID leader Alvin Plantinga (68, 74). Pennock (62) responded to Dembski's claim (15) that ID does not resort to magical reasoning but that evolution does.

Although scientists understand the practice of science, most are unfamiliar with the theoretical justification of scientific methods; by shifting the point of

attack to these philosophical issues, Johnson and other ID theorists aim to put them at a disadvantage. Indeed, some have inadvertently helped the ID cause by denying any distinction and claiming that supernatural creation can be treated (and rejected) like any other scientific hypothesis, thereby confirming atheism, without understanding how methodological naturalism is an evidential requirement (69). The ID movement is happy to promote the views of such scientists because it supports their claim that ID is a real scientific alternative. Scientists who are familiar with the philosophy of science such as Stephen Jay Gould have not made this error when pointing out the many problems with Johnson's work (32).

Teach the Controversy

In the battles at state boards of education and local school districts, creationists continue to find new ways to press their attack. As we have seen, changing euphemisms for creation regularly cloud the debate. The call for balanced treatment mutated into a call for teaching evidence against evolution (78), and today one also regularly hears the new Wedge slogan to "teach the controversy". ID leaders Stephen C. Meyer and John G. West, Jr. appealed to this in the Ohio Board of Education case (42, 92). The ID-drafted Santorum amendment, mentioned above, used this language as well, singling out evolution as controversial. Of course, there is a political and religious controversy about evolution, but the Wedge strategy is to spin the term to suggest that evolution is scientifically controversial (92). Scientists need to clearly point out this distinction whenever such deliberately ambiguous claims are made. Generic appeals to fairness may play well, but this an inappropriate standard when discussing science, which demands evidence before a conclusion can be taken on board. Similarly, the generic argument that excluding ID theory violates academic freedom is a perversion of that concept; with freedom comes responsibility, in this case the responsibility to maintain professional standards, and ID fails to meet minimal scientific standards.

Pennock discusses why it would be a mistake to bring the political and religious controversy into the science classroom, and how the issue would have to be addressed in the classroom if it happened (64). Science educators need to think carefully about how best to teach evolution in light of the ongoing challenges. One of the best sources of sound practical advice to teachers is *Defending Evolution: A Guide to the Creation/Evolution Controversy* (2) by Brian J. Alters, Director of the Evolution Education Research Centre at McGill University, and Sandra M. Alters, a biology textbook author. The Evolution and Nature of Science Institute's web site also provides useful teaching materials (4).

Viewpoint Discrimination

Another argument Wedge members make is that ruling out dissenting voices on the evolution question, even religious ones, amounts to viewpoint discrimination (57). Following Philip Johnson's lead (36), the term is chosen deliberately for its possible legal utility, keying on court decisions that have allowed inclusion of

religious viewpoints in public schools under certain circumstances. Other Wedge members have since developed the idea in a legal guidebook for ID proponents (17) and a law review article (18). The Wedge is clearly preparing for the third phase of its strategic plan, which includes "possible legal assistance in response to resistance to the integration of design theory into public school science curricula" (19).

Law professor Jay Wexler, an ID critic, is sympathetic to the complaint that public education makes religion appear unimportant and that evolution may foster that view. He argues that there may be reason and legal justification to include instruction about religious views of origins in social studies classes. However, he rejects the proposal that ID may be included in science classes and dismisses the viewpoint discrimination argument and other arguments of ID activists (93). To date, no lawsuits have been filed so it remains to be seen whether the courts will allow the ID movement to get the thin edge of its Wedge past earlier decisions against teaching creationism in public schools. However, we can expect such a trial in the near future, the timing of which may depend in part on how the membership of the Supreme Court changes in the coming years.

RECOMMENDATIONS

Many scientists have found it easy to dismiss or ignore creationism, but they have done so at their own peril for apathy has led to unexpected creationist victories, if only temporary ones, which cause damage to the profession that is often difficult to fix and will likely have cumulative negative impact. Moreover, because the account of creation is of such theological importance to fundamentalists and evangelicals, and because this religious movement is so large and politically powerful in the United States, creationists will not likely give up anytime soon. What can scientists do to be more proactive about this issue and to be better prepared to defend science education against what ID creationists resolve will be a generations-long culture war? I expand on the AAAS Board's recommendations and then conclude with a few additional suggestions.

Improve Understanding of the Content of Evolutionary Theory

The AAAS Board's goal is to educate policy-makers about evolution. This is clearly important, but the scientific community and especially academic scientists need to put their own house in order as well. For instance, too few university biology departments explicitly require an evolution course. Theodosius Dobzhansky famously said that nothing in biology makes sense except in the light of evolution (20). However, scientists too often assume that the fundamental importance of evolution is obvious and thus fail to make the connections apparent for students. Even better than a required evolution course would be to thoroughly and explicitly integrate evolution in every biology course. This is easy to do in

genetics courses, and there is no reason that it couldn't also be done in courses on cell and molecular biology, plant and human biology, anatomy and physiology, and so on (8, 53, 76). Such a systematic incorporation would do more than anything to help students understand Dobzhansky's point that evolutionary theory is biology's unifying explanatory framework.

Improve Understanding of the Nature of Science

However, in fulfilling the above recommendation, it is important that science programs not simply add a list of evolutionary facts. Teaching science as just a set of facts to be memorized obscures what is most distinctive about the nature of science, namely, that its conclusions are to be accepted or rejected on the basis of evidence, not authority. Students need to learn directly about the nature of scientific reasoning (40). This means that they need to spend more time in inquiry-based learning, where they can experience the process of hypothesis testing first-hand. Lectures need to include something about the history of inquiry that led to the current state of the art, even if that means other facts have to be left out. Learning real philosophy of science rather than simply taking for granted what is usually a simplistic notion of "the scientific method" is also important (81).

With regard to the creation/evolution controversy, many misunderstandings could be avoided if more attention were paid to the nature of science. Eugenie Scott, a physical anthropologist and director of the NCSE, consistently stresses the importance of having teachers "distinguish between where science leaves off and where philosophy begins" (77). To improve understanding of the nature of science in this and other ways is probably the most important thing scientists and science educators can do.

Do Not Inappropriately Mix Science and Religion

Scott gives sound advice regarding this, suggesting "that scientists can defuse some of the opposition to evolution by first recognizing that the vast majority of Americans are believers, and that most Americans want to retain their faith." Scientists, she says, should "avoid confusing methodological naturalism and metaphysical naturalism" and "avoid making theological statements (such as those concerning ultimate purpose in life, or final cause) in the context of their scientific discussions" (77). This is not to say that scientists may not form their own views about philosophical and theological issues, or that they should not discuss them, but rather that when they do so they explicitly note that they are not speaking *qua* scientist. Again, this simply respects the limits of what can be investigated from within science. Scientific findings certainly have a place in philosophical and theological arguments that may eventually lead one to draw a metaphysical conclusion, but such arguments lie outside of science. By itself, science is neutral with respect to metaphysical possibilities.

Keep Scientific Results in Perspective

This advice is primarily aimed at science writers, but it applies to teachers and researchers as well. One can understand the journalistic desire to punch up a story, but it is misleading to exaggerate the significance of new scientific findings. Not every new fossil find requires that the tree of life be redrawn. Most scientific discoveries fit well within existing frameworks or lead to relatively minor modifications, and it misrepresents the nature of science to suggest that every finding is revolutionary.

Scientists would also do well to heed this advice. Many have absorbed philosopher and historian of science Thomas Kuhn's notion of scientific revolutions, and would love to have their work initiate one, but in point of fact only a small number of scientific discoveries effect a paradigm shift. The vast majority of research falls under what Kuhn called "normal science" and that is all to the good. For instance, some hot internal debates about the tempo of evolutionary change or the relative contribution of natural selection to the same simply provided fodder for creationists who were only too happy to quote the sometimes extreme statements of scientists as indication that the whole field was in disarray. Issues that are relatively minor in relation to the fundamental theory may seem momentous to specialists, but it behooves everyone to keep things in perspective, particularly when explaining science to the public.

Honor and Provide Incentives to Scientists Who Teach

In his book *Denying Evolution: Creationism, Scientism, and the Nature of Science*, biologist Massimo Pigliucci provides a useful list of things scientists need to do if they are to make progress in the creation/evolution controversy, including changing hiring practices, providing teacher training and continuing education, supporting interdisciplinary courses, improving textbooks, abandoning the lecture format and "canned" activities with predetermined outcomes, and sponsoring "community days." (67). But to give scientists an incentive to come down from the ivory tower, there needs to be a change in the system of professional rewards.

All scientists understand that basic research is the raison d'etre of science, and incentive structures in the scientific community have historically reflected that priority. Scientific reputations, not to mention salaries and prime lab space, are won and lost as a function of research grants and publications. However, little attention is paid to science and little basic research is funded by governments (or administrations) that do not value science as a way of knowing. It is only within a culture that appreciates science that the necessary infrastructure can be sustained and research can flourish. A scientific culture depends on public support. If only for this reason (and certainly it is not the sole or most important one), it is in the enlightened self-interest of the scientific community to reward its members who explain and pass on the ideals and excitement of science to students and to the general public. The incentive structure currently underestimates the importance of this crucial role to the profession, and it behooves scientific societies to

correct the balance. AAAS should not just ask its members to pay attention to science education and public policy, it should propose and implement appropriate incentives.

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