

REPORTS

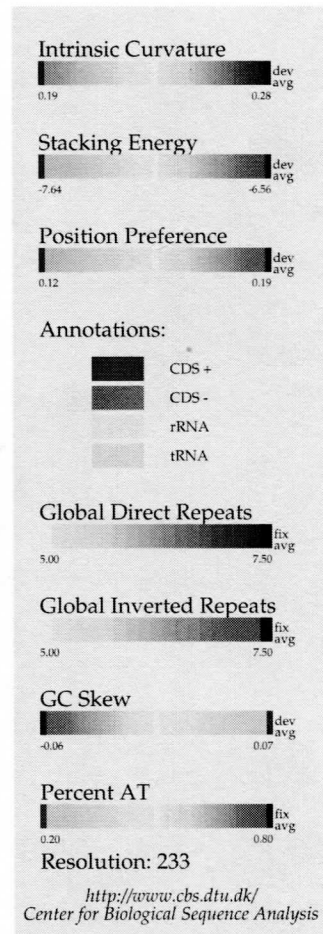
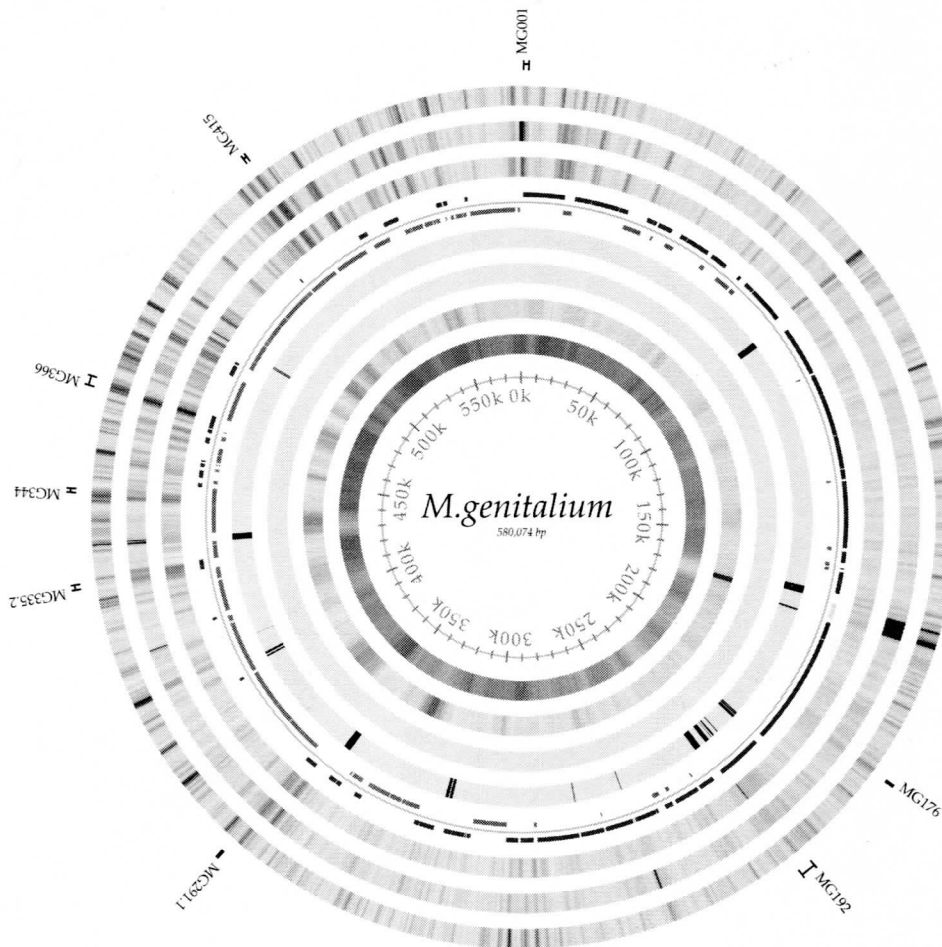
OF THE
NATIONAL CENTER FOR SCIENCE EDUCATION
DEFENDING THE TEACHING OF EVOLUTION IN THE PUBLIC SCHOOLS



Volume 22, Number 5

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CONTINUES NCSE REPORTS &
CREATION/EVOLUTION

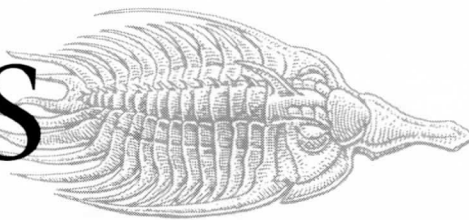


Books: *Darwin: The Power of Place; Who Wrote the Book of Life?*

Yes, Virginia, There is a Universal Genetic Code; Meet the Mycoplasmas

Ohio Board of Education Rejects "Intelligent Design" in Science Standards

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For more information on Ray's work explore his website at <www.trollart.com>.

IN THE NEWS

As this issue of *RNCSE* goes to press, we have word that the Ohio Board of Education approved science education standards that remain strong on evolution and has resisted efforts to include "intelligent design" theory or the admonition to "teach the controversy" in K-12 classrooms. Last-minute compromise language and amendments were presented to the board. We will have a complete wrap-up of the board's action in the next issue, but in this issue we bring you a perspective by Ohio Citizens for Science activist Patricia Princehouse.

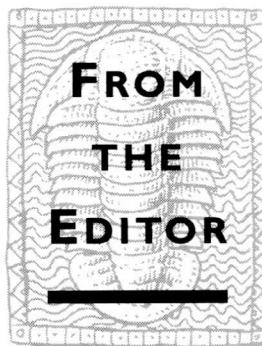
Of course, anti-evolutionism is not asleep in other parts of the country. The school board of Cobb County, Georgia, voted to continue using disclaimers about evolution in its textbooks and revisited its controversial "theories of origins" policy. Skip Evans reports on opposition to the disclaimers and related issues.

"What's in a name?" asked Juliet Capulet when she discovered that her lover Romeo's name interfered with the aspirations of her heart. Her advice to "deny thy father and refuse thy name" has been taken to heart at the Discovery Institute's newly renamed Center for Science and Culture. Not only has the name changed, but, as Glenn Branch points out, the visual imagery on the CSC's has, too. The trend is away from overt religious imagery and symbolism and from references to nonscientific goals of the Center.

ALL ABOUT YOU!

Our NCSE News section is brimming with news of you, our members. Glenn Branch brings you up to date in this issue. We also acknowledge in this issue those whose financial support to NCSE has helped us through another eventful year.

We are also pleased to report exciting news for two long-time NCSE members. NCSE Supporter Dr Johnetta B Cole has come out of retirement to accept the presidency of Bennett College, one of only two institutions of higher learning in the



United States for women of African descent. And Steve Randak, who was featured in the PBS *Evolution* series, was named the first-ever recipient of the

National Association of Biology Teachers' Evolution Education Award.

Please keep the NCSE office informed of your activities and awards so that we can brag about them in print.

SCIENTIFIC ARTICLES!

Anti-evolutionists from the beginning of the 20th century used the conservative nature of genetic transmission to argue that evolution was impossible. In the 1930s, the Modern Synthesis put those claims to rest — or so we thought. Now, anti-evolutionists are claiming that new information from the study of genomes refutes the evolutionary claim of common ancestry for all living things on earth. They claim that variations from the expected "universal genetic code" are proof of either separate origins or the intervention of an "intelligent agent" into the history of life on earth.

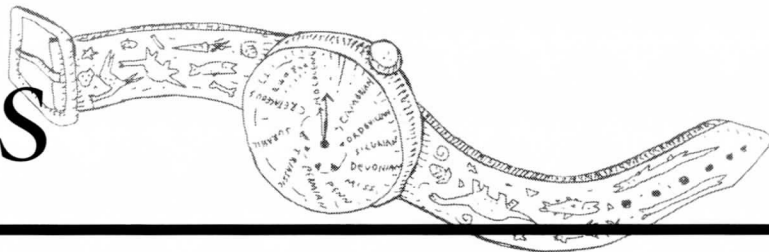
In this issue, Finn and Jean Pond take on the claims by the Discovery Institute that genomic research rejects the evolutionary prediction of a "universal genetic code". To the contrary, the Ponds demonstrate, even the deviations from the standard DNA-RNA-protein connection can be explained by ordinary — and previously observed — processes of evolutionary change.

Later, Michael Buratovich explores the genomics of the mycoplasmas — one of which graces our cover. Does the mycoplasmic genome refute evolutionary theory, as some creationists suggest? Not at all, says Buratovich; these organisms show a variety of modes of evolutionary change found among the other microorganisms that are close relatives of the mycoplasmas — just the sort of pattern common descent would anticipate!

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REPORTS



Ohio Overthrows Scopes Legacy

Big loss for the Discovery Institute and "intelligent design"

*Patricia Princehouse
Ohio Citizens for Science*

Could God have made the world using 25-hour days? Or 25-million-year days? Even William Jennings Bryan had no doubt that He could. And only 9% of Ohio scientists say they cannot square evolution with belief in God.

Yet for 77 years the legacy of the Scopes trial kept evolution out of science education in Ohio for religious reasons. A unanimous Ohio Board of Education (OBE) vote on October 15, 2002, means that virtually all Ohio high school students will finally be introduced to evolutionary theory beginning in 2003. The new standards are a great victory for Ohio's students, but also for Ohio's economy, as better biology instruction will prepare students for the demanding biotech jobs that are starting to come to Ohio.

Contrary to popular belief, Scopes lost his trial. Laws were on the books until 1968 that prohibited K-12 teachers and professors in public universities in many states from even using textbooks that mentioned evolution. After the laws were repealed, most states gradually added more evolutionary biology to their standard curricula, but Ohio balked. Lawrence S Lerner's report on evolution education in America gave Ohio an "F" and commented, "In Ohio, the E-word is avoided" (*Good Science, Bad Science: Teaching Evolution in the States*, 2001).

OHIO'S 2002 STANDARDS

On the heels of Kansans' reversal of their anti-evolution blunder, the OBE hired an expert panel of scientists and educators to develop science standards that would give students a

cutting-edge education. When it became clear to creationists that this would involve evolution, they adopted a novel strategy with guidance from IDnet in Kansas and the Discovery Institute in Seattle. Instead of trying directly to keep evolution out of the standards, they would demand that alternative "scientific" theories also be taught.

In the past, the "scientific" alternative has been "creation science". But the 1987 Supreme Court decision in *Edwards v Aguillard* clearly declared *that* approach unconstitutional. So opponents of evolution called upon the new, vaguer "science" of "intelligent design" (ID). There appeared to be two goals in Ohio: 1) anti-evolutionists hoped to convince Ohio to include ID in its new science education standards; 2) failing that, they hoped that the resulting confusion over what should and should not be taught would minimize new evolution content. They did not succeed in promoting their first goal with the science educators on the standards writing committee, so in January 2002, they convinced the full board to listen to a speech by lawyer John Calvert of Kansas on why ID should be required in the standards.

What anti-evolutionists did not expect was that Ohio's major newspapers would splash headlines across their front pages announcing that creationists were targeting the new science education standards. The result was a groundswell of support for evolution education. Within 2 weeks, an organization was formed to promote good science education, including evolution — Ohio Citizens for Science (OCS). OCS swiftly put up an informational web site (<<http://www.ohioscience.org>>). The journal *Science* commented on the situation in its February 8, 2002, issue, and across the state "ivory-tower" scientists joined hands with parents and

Patricia Princehouse teaches evolution, and the history and philosophy of science at Case Western Reserve University in Cleveland, Ohio.

clergy, Republicans, Democrats, and others to ensure good, religiously neutral, science education for Ohio's students.

On March 2, Case Western Reserve University sponsored an event in downtown Cleveland called "Evolution and God: Why 'Intelligent Design Theory' is not Science" (see *RNCSE 2002 Jan-Apr; 22 [1-2]: 8-9*). Kenneth R Miller, Lawrence Krauss, Cynthia Beall, and I discussed the issue before an unexpected packed house; over 2500 people showed up, and we even had to turn away a couple hundred for lack of seats! None of us knew that this event would be such a powerful draw. But more important, the CWRU event focused attention on the problems with ID and galvanized support for good science education throughout the state. There was more press coverage in favor of evolution education, and more evolution supporters began contacting the OBE, other office holders, and the press.

After this event, OCS started an online petition addressed to the OBE respectfully asking it not to include ID in the new science standards. In less than a month, over 3000 people had signed, and many included thoughtful comments. These were presented to the board. With such a large and enthusiastic turn-out in support of evolution and against ID, the OBE recognized that support for evolution education in Ohio was strong, widespread, and vocal. From that point on, we perceived increased attention to and respect from the OBE for the objections we raised against attempts to weaken evolution education.

THE DISCOVERY INSTITUTE RESPONSES

A week after the CWRU event, the OBE hosted a panel discussion with Krauss, Miller, and two Senior Fellows of the Discovery Institute's Center for the Renewal of Science and Culture, Jonathan Wells and Stephen C Meyer. To the amazement of all, the DI con-



tingent conceded defeat! Rather than complying with the board's request to present arguments that ID should be mandated in the science education standards, they took ID off the table. Instead, Wells tailored his comments to the question: "Should teachers be *permitted* to tell students about the scientific controversy over 'intelligent design'?"

Since science education standards only specify the minimum a student should be tested on, they in no way prohibit teachers' use of additional content of any kind, so the argument is a red herring. Even if the board of education were to issue a special statement encouraging teachers to teach ID or "creation science", it would still fail constitutional and statutory tests. Besides, Wells and the DI had yet to demonstrate that there was indeed a *scientific* controversy over "intelligent design".

Meyer's testimony attacked Krauss's contention that proponents of "intelligent design" have published no articles in peer-reviewed journals in two ways. First, he pointed out that new ideas in science are often first presented in books. That point is fair enough, though he misrepresented Darwin as an example of this contention (Darwin co-authored an article with Wallace in the *Proceedings of the Linnaean Society* in 1858, a year before publishing his *Origin of Species* book — information so widely known that it seems inconceivable that Meyer was unaware of this). However, he was unable to provide examples of any other material proposed for inclusion in the K-12 science education standards material that did not have substantial support from peer-reviewed scientific research journals.

Second, Meyer claimed that the question at issue mainly concerned whether there exists enough "dissent from Darwinism on the question of design versus apparent design" to warrant inclusion of such dissent in the science standards. He then presented an annotated bibliography of "some 40 peer-reviewed articles that question aspects or key tenets of Darwinian theory and that is also part of the growing dissenting opinion that forms this controversy" (see RNCSE 2002 Jul/Aug; 22 [4]: 15-8, 23).

As the NCSE analysis of the DI bibliography shows, the 44 articles cited in this bibliography included no

research by proponents of "intelligent design" theory; no discussion of "design versus apparent design", and no articles that challenged evolutionary theory (see RNCSE 2002 Jul/Aug; 22 [4]: 15-8, 23-4). I am happy to report that the OBE was not taken in by this specious argument.

Perhaps the most serious challenge that Meyer proposed to the board was to consider a compromise that would "teach the controversy" about "origins science". His proposal had 4 parts:

- 1) Coverage of ID would not be mandated in the standards;
- 2) Standards *would* mandate "mastery of scientific evidence and arguments for and against the theory" of evolution;
- 3) Standards would make clear that the standards *permit* teachers to tell students about alternative views that exist within the scientific community about the origin of new life forms, including the view of scientists who favor the theory of "intelligent design";
- 4) OBE would enact "no definition of science that would prevent teachers from discussing these alternative evidence views."

Of course the OBE had no choice but to comply with item 1: legal and constitutional constraints exclude such a mandate. Taken literally, item 2 would require each student to do advanced graduate work in evolutionary biology (not necessarily appropriate for K-12 education), so we supposed what Meyer really had in mind was that schools use Wells's *Icons of Evolution* or some similar material. Furthermore, item 2 must avoid unconstitutional entanglement with religious motivations for including "evidence against", which has been scuttled by public testimony at OBE meetings. Perhaps that knowledge was behind the "Supplemental Bibliography".

Science education standards do not make statements either for or against material that is *not* mandated, so item 3 falls outside the scope of these standards and is irrelevant to the purpose of the standards. In a similar vein, item 4 pretends that somehow the nature of science depends on what is or is not included in the standards document, rather than the

opposite — that what is in the standards depends on the nature of science.

In order to bolster their claims that this is a scientific controversy, Ohio ID proponents hit the press a couple weeks later with a statement signed by 52 Ohio scientists in support of "teaching the controversy". Finally, the writing committee was to meet and make its final decision about the science education standards. Some 6 months later, the writers' final draft of the standards contained substantial material about evolution, nothing on "intelligent design", and nothing that could be construed as "teaching the controversy". This constitutes a major victory for good science education in Ohio.

THE LAST GASP

In response to the final draft, the activist OBE members went into high gear. A week before the October meeting at which the standards were to be voted on, they floated a proposed amendment along the lines of Meyer's point 2: "Know that scientists continue to debate the mechanisms of evolution today. Describe scientific evidence, from the fossil record, homology, and embryology, which supports as well as challenges current evolutionary theory."

That same week, Case Western Reserve University and the University of Cincinnati announced the results of a major poll of Ohio scientists on their views on the scientific nature of "intelligent design" and evolution. The poll consulted some 500 scientists at secular and religious colleges and universities in Ohio (including fundamentalist schools that teach young-earth creationism). Nine out of 10 scientists (91%) felt the concept of "intelligent design" was unscientific and that "intelligent design" was "primarily a religious view". A vast majority (93%) of the scientists said they were not aware of "any scientifically valid evidence or an alternate scientific theory that challenges the fundamental principles of the theory of evolution". Almost all scientists (97%) said that they did not use the "intelligent design" concept in their research, and 90% of the responding scientists stated that they felt no scientific evidence supports "intelligent design". Only 2% felt that "intelligent design" was strongly supported by scientific evidence. Only 9% felt that



accepting the theory of evolution was not "consistent with believing in God".

CWRU Biology Department chair Joseph Koonce commented at the press conference announcing the poll:

I want to make clear that I am a religious person myself. As a Roman Catholic, I do believe in God and in concurrence with teachings of the Church, I have never found these beliefs in conflict with evolutionary theory. Science addresses the nature of the physical universe, not the supernatural or the eternal... I wish this would lay to rest the destructive notion that science and religion are at war in America. There is no such inherent conflict. Science and religion can promote and enhance each other without having to pretend we know less than we actually do about how the world is constructed and how it functions.

George Bishop, director of the University of Cincinnati Public Opinion Laboratory, IPOL, also addressed 2 questions to the general public on the September Ohio Poll and found that: "Despite significant coverage and editorials on the ID issue in Ohio's news media in recent months, most Ohioans still know little or nothing about 'intelligent design'." Respondents were first asked: "Do you happen to know anything about the concept of 'intelligent design'?" Eighty-four percent said "no", 14% said "yes", and the rest (2%) were "not sure". Not surprisingly, significantly more college graduates (28%) said that they knew something about it than did high school graduates (7%) or those with less than a high school education (6%). Whether they knew anything about it or not, respondents were then given a brief description of the concept of "intelligent design" identical to the one used in a statewide *Cleveland Plain Dealer* poll conducted this past spring: "The

concept of 'intelligent design' is that life is too complex to have developed by chance and that a purposeful being or force is guiding the development of life." Given this description, 54% of Ohioans viewed it as basically a religious explanation of human origins; only 23% thought it was a valid scientific account.

Faced with these results, the activist board members revised their demands, substituting the line "Describe how scientists continue to investigate and critically analyze aspects of evolutionary theory" for their earlier, unconstitutional language, and asking to substitute part of the Ohio Academy of Science's description of science for a line in the "Scientific Way of Knowing" section. The standards subcommittee evidently let the amendments through as a face-saving measure, but insisted that references to the age of the earth (4.5 billion years ago) and the date of appearance of earliest life (4 billion years ago) be included as well.

The standards were then passed by the subcommittee, and the next day the entire board voted an "intent to adopt" (the final vote will be in December). Board member Michael Cochran clarified that these modifications do not promote teaching ID: "I want to echo specifically that, as one of the makers of this motion, and involved in the conflict, as I mentioned earlier, in no way for the record believe that this at all advocates for the teaching of creationism in school or 'intelligent design'." Deborah Owens-Fink concurred: "I think it is important to state what this is not. This is not ID. ID is specifically not mentioned and will not be tested. This is not [a] religious perspective."

A WIN-WIN SITUATION?

Anti-evolutionists, of course, immediately claimed victory (readers may remember that when the creationists were voted off the school board in Kansas and the new board restored evolution, Phillip Johnson claimed that as a victory, too). A week after

the OBE vote, Johnson was in Ohio to explain to disgruntled young-earth creationists (YECs) what a good thing the board decision was. He worked hard to convert the YECs to ID, saying "Either you're going to teach that God did it, or that it was done without God." "If we put this controversy in biblical terms", he said, "the place to start is not Genesis [but] John 1:1 — 'In the beginning was the Word'." He even commented that "Kansas took a similar step, but it was not as well planned. And Kansas is a marginal state — not one the Eastern establishment pays much attention to." And, he emphasized, "They flinched."

Johnson's attacks on evolutionary biologists — and the young-earth creationists' dismay — seem extreme if the OBE decision indeed represents a victory for them. But then, I repeat what I said to an Associated Press reporter on this matter: "We won big time here. The creationists have lost. There is more evolution in the standards now than there would have been had they kept their mouths shut."

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The Debate Over Ohio's Science Curriculum is not over Academic Freedom or Balance

Dennis D Hirsch

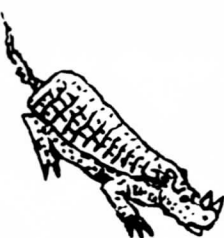
Fresh on the heels of its defeat in Kansas, the "intelligent design" movement came to Ohio advocating that, along with Darwinian evolution, our public schools teach that complex life-forms are the work of an "intelligent designer". It demanded that the state science standards, which the State Board of Education will revise by December of this year, encourage the teaching of this idea.

Dennis D Hirsch is an associate professor of law at Capital University in Columbus, Ohio.

DI CLAIMS VICTORY IN OHIO

Shortly after the OBE adopted science education standards for Ohio students that repudiated appeals to include "intelligent design" and to "teach the controversy" about evolution, the Discovery Institute posted its victory statement nevertheless:

<http://www.discovery.org/news/ohioBoardBacks.html>.



There are many good reasons to reject this request, including the Ohio Academy of Science's conclusion that "intelligent design" has "no scientific validity ... [and] should not be taught as science" in the biology classroom. But perhaps the strongest reason, one that has gotten little attention, is that under the US Supreme Court's 1987 decision in *Edwards v Aguillard*, granting the request would violate the Constitution.

This decision concerned a Louisiana statute that instructed public schools to teach "creation science" alongside evolution. There, as in Ohio, the proposed addition to the curriculum included the idea that an "intelligent mind" created the living world, and its proponents claimed that this constituted a valid scientific theory, not a religious one.

In no uncertain terms, the high court found that the Louisiana statute violated the First Amendment's Establishment Clause. The key question was whether the statute, which purported to serve the secular goal of promoting academic freedom, was, in fact, motivated by impermissible religious ends.

The court cited one proponent's statement that creation science included a belief in a "supernatural Creator" and another's that the theory of evolution conflicted with his religious beliefs. Statements such as these were sufficient to convince the court that the statute was religiously motivated and, therefore, unconstitutional.

Conscious of the *Edwards* decision, the "intelligent design" movement has been careful in its dealings with the Ohio State Board of Education not to identify itself publicly with religion. As Bob Lattimer, a leading "intelligent design" advocate in Ohio, recently admitted to *The (Cleveland) Plain Dealer*: "It's God, sure. ... But everyone doesn't have to say that. I suppose it goes back to the status of the legal situation, that if they can pin down [who "intelligent design" proponents think the designer is], it might affect whether the courts view the movement as an attempt to endorse a religious belief."

Until recently, artful behavior of this type largely has succeeded in obscuring the religious motivations of the "intelligent design" movement. That may change soon. Barbara Forrest, an associate professor in the Department of History and Political

Science at Southeastern Louisiana University, has published an article that exposes the extreme religious agenda that lies at the heart of the effort to shape our school curriculum.

Forrest shows that Phillip Johnson, a founder of the "intelligent design" movement, and the Discovery Institute, a conservative Seattle think tank that is leading the effort, steadily are advancing what they call the wedge strategy. As Johnson and the institute see it, American society is in the grip of a "materialist" ideology, referred to by most people simply as the natural sciences, which does not adequately recognize the central role of God. According to wedge advocates, this intellectual cancer has "infected" almost all parts of society.

Virtually all mainstream religions accept evolution, and people who heard Johnson speak in Kansas said he referred to such "liberal Christians" as "worse than atheists because they hide their naturalism behind the veneer of religion."

Johnson views materialist culture as monolithic, analogous to a log. In a 1997 book, he explained that even a log can be split by driving a wedge into a crack and gradually widening the split. Evolutionary theory is the crack; the "intelligent design" idea is the wedge. The goal is the return of a "broadly theistic understanding of nature" that will lead to a cultural renewal driven by the wedge advocates' brand of Christianity.

Forrest reports that the Discovery Institute has gone so far as to prepare a strategic plan for achieving this via a program of "5-year objectives" that includes having "10 states begin to rectify ideological imbalance in their science curricula and include design theory".

We now can see where Ohio's public schools fit into the picture. These statements and others that Forrest cites in her article go far beyond those that the Supreme Court found in the *Edwards* case sufficient to declare the statute unconstitutional. Forrest's research, therefore, demonstrates convincingly that the effort to insert "intelligent design" into the public-school curriculum is religiously motivated and, as such, violates the Constitution.

But it does more than this. It shows that the debate over Ohio's science curriculum is not over academic freedom or balance or any of the other trumped-up reasons for ignoring sci-

entific standards and giving special preference to an unproved idea. Rather, it is part of a radical national strategy by a group of committed advocates for blasting a hole in the natural sciences, so as to import their version of religion. And they want to use our public schools to do it.

What the State Board of Education and all Ohioans need to decide is whether we want to be party to this effort.

Reprinted from the Columbus Dispatch 2002 Jun 13.

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Position Statement from the Ohio Citizens for Science

Ohio K-12 Academic Content
Standards for Science

The Ohio Citizens for Science accepts the current draft of the Ohio Academic Content Standards for Science, albeit with reservations. The Ohio Department of Education, with its appointed science writing and advisory committees, has proposed a commendable package of standards that establish a sound foundation for quality K-12 science education in Ohio.

On some issues, the standards for biological science have been compromised for political rather than pedagogical reasons. Previously we have offered our support and suggestions via every available avenue, but must express our regrets on two key issues:

The uniform deletion of the term *origin* from the standards is pedagogically unsound and indefensible. All scientific disciplines are relevant to issues of *origins*, and the Ohio standards should reflect that reality.

Using the term "Evolution theory" (which should read "Evolutionary theory") depicts the dynamic nature of biological science, but the word *theory* is too often neglected in other realms of science. It would be prefer-



OHIO PUBLISHES REVISED SCIENCE STANDARDS

The October 2002 draft of Ohio's science education standards are now available on line at http://www.ode.state.oh.us/academic_content_standards/sciencecontentstd/default.asp.

able to validate the theoretical dynamics of disciplines such as chemistry and physics. Ohio should not subtly call into question the basic tenets biological science with the vernacular use of the term *theory*. We encourage critical thinking regarding all scientific hypotheses and theories in each scientific discipline.

There are also specific indicators and benchmarks that could have been worded with greater precision and accuracy, including those regarding the origin of life. Nevertheless, we recognize that a qualified science educator in the Ohio K-12 educational system who reads the standards carefully should still be able to implement the standards appropriately in the classroom, and effectively portray contemporary scientific consensus and methodology.

We are pleased that the standards have moved forward rather than backward. The previous *Ohio Model Curriculum* was devoid of evolutionary theory; now our students can benefit from standards that reflect the evolutionary cornerstone of biology. Moreover, the new standards, while compromised, do not include doctrines that fall outside the realm of science.

Thus, we recommend that the Ohio Board of Education adopt the set of science standards proposed by the Ohio Department of Education.

The Ohio Citizens for Science are keenly aware that some people of faith have serious concerns about the teaching of evolutionary theory in Ohio schools. Our members represent many religions and include clergy, each of whom see no conflict between their beliefs and the teaching of evolutionary theory in the science curriculum. Yet in order to address the genuine and sincere nature of religious beliefs held by some Ohio citizens, we recommend that the Ohio Board of Education consider developing curricular materials on the history of science and religion that could be offered as potential topics for social studies teachers throughout the state.

Is ID a Controversy Worth Teaching?

Jennifer Palonus

Being an avid student of the creation/evolution debate, I had followed the antics of the "intelligent design" (ID) movement in Ohio with great interest. After the Board of Education's October 15 vote, some of the initial press reports had mentioned the Discovery Institute's "teach the controversy" argument. I wanted to know how this was playing with the board members. Did they feel ID was a legitimate scientific theory that their students should know about, or was "the controversy" little more than a public-relations phenomenon? I was able to reach, by telephone, three members of the board who had been prominent in the standards design process: Deborah Owens-Fink, Marlene Jennings, and Martha Wise.

Dr Deborah Owens-Fink teaches marketing and international business at the University of Akron. She has a BS in engineering and an MBA and PhD in marketing from Ohio State. She is enthusiastic about exposing students to areas of controversy within the subjects they are taught. She has been convinced by her teaching experience that exposing students to controversial theories excites them and can be a potent way to keep them engaged in the subject and interested in learning more.

Owens-Fink was impressed by both the anti- and pro-ID scientific testimony, and she does not consider ID as necessarily being on the fringe. But her background is not in biology, and she freely admits that before the hearings she was not at all familiar with the wider creation/evolution debate. She also did not seem familiar with the back stories and hidden agendas that drive the creation/evolu-

Jennifer Palonus runs *Creation/Evolution: The Eternal Debate*, a creation/evolution news portal and discussion board, at <http://crevo.bestmessageboard.com/>.

tion debate. At one point she mentioned that she did not think that ID was only being promoted by people with a religious agenda. As examples of skepticism about evolution not motivated by Christian theology, she mentioned Haldane's Dilemma and the theories of Fred Hoyle. She did know that the well-known ID author Jonathan Wells is a member of the Unification Church of Sun Myung Moon, yet she interpreted this as evidence that not all IDists are fundamentalist Christians.

Evolutionists familiar with the creation/evolution debate roll their eyes at examples such as these. The idiosyncratic physicist Fred Hoyle is going to achieve a kind of immortality, as creationists quote his strawman argument that life's forming from organic chemicals was as likely as a tornado blowing through a junkyard and assembling the pieces into a 747. And some creationists argue that evolutionist JBS Haldane's 1957 paper "The cost of natural selection" (*Journal of Genetics* 55: 511-24), which introduced "Haldane's Dilemma", proved that there has not been enough time since humans diverged from the chimpanzees to account for all the genetic differences between our two species, while evolutionists patiently point out that argument's numerous flaws.

Meanwhile, Jonathan Wells is a man on a mission. He has explicitly revealed (in Unificationist publications only) that shortly after he joined the cult in the late 1970s and after meeting the Reverend Moon, he "decided to devote [his] life to destroying Darwinism" (see <http://www.tparents.org/library/unification/talks/wells/DARWIN.htm>).

I tried to get Owens-Fink's reaction to Wells's "destroying Darwinism" admission, but she cut me off: "People's motives aren't relevant", she insisted. "It's the scientific arguments you have to look at." She was emphatic about avoiding anything that hints at an *ad hominem* approach to assessing the arguments.

It is not easy to find scientists who deny the major tenets of evolution who do not already have an obvious religious agenda. But I sure didn't expect to find creationists on the board who were against adding ID to the Ohio standards!

Board member Marlene Jennings was one of the most outspoken oppo-



nents of adding ID to the curriculum. She mentioned to me twice, almost in passing, that she believes creationism will win out in the end as science makes new discoveries. I had to make sure I heard her right.

"Yes, I think creationism is true. That's part of my belief structure", she said.

And yet as the testimony progressed through spring and summer, she had become convinced that "the evidence just isn't there yet."

Jennings has a BA in math, as well as a JD, and has always been interested in science. She agrees that exposing students to controversial topics can be a useful tool. But as the pro-ID scientists testified, she found herself asking them such questions as "have you actually seen this dividing line between micro- and macro-evolution?" and "which biological structures that you work with look like the products of design instead of evolution?" She was not impressed when the scientists could not give her a straight answer. The turning point for her was when they could not give her any examples of "independent free-standing evidence for design", as opposed to just negative assertions against evolution.

Jennings seems to be unimpressed by credentials *per se*. She noticed that several of the pro-ID scientists who confidently asserted the plausibility of ID were speaking outside their areas of professional expertise. "There are a lot of scientists out there who[m] you wouldn't give a lot of credibility to at all", she concluded.

And Jennings was not the only creationist on the board who ended up a skeptic of ID as a scientific theory. Martha Wise, who after 24 years is the *grande dame* of the board, was quick to mention, "I don't want to be painted into the evolution corner, because I am a creationist." But Wise is quite comfortable that "God hasn't told us everything yet." It is just that "it takes science to discover the details and resolve the contradictions in knowledge." In this sense, "creation and science are compatible."

And Wise does not think "intelligent design" rises to the level of a scientific theory. "What theory? There are no other theories" except evolution. "There is no scientific evidence" for the other side. "They think there is, but there isn't." "There are 17 of us [board members] who do not have enough of a background in science to

evaluate it ourselves." But the pro-ID forces "are coming at this through a political process, not the scientific process."

It seems the ID proponents had the same problem convincing a majority of the board members as it does convincing scientists in general: they still have not been able to articulate a positive scientific case for "intelligent design". ID is still just a collection of negative claims about evolution. And sniping at the dominant paradigm does not a scientific revolution make. The only positive argument they have for their theory is the religious one — that getting many people to believe in it will help to renew society. Unless they can ever get beyond this stage, the ID movement will likely remain stuck on the fringes of science and out of (most) classrooms.

[Excerpted, with permission, from "Ohio's saga approaches an intermission"; for the complete article, see <<http://crevo.bestmessageboard.com?vThreadID=227>>.]

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Cobb County, Georgia: A Textbook Case

Skip Evans
NCSE Network Project
Director

GEORGIA ADOPTS NEW TEXTBOOKS

On March 28, 2002, the Cobb County (Georgia) Board of Education voted to adopt nearly 8 million dollars' worth of science, health, and physical education textbooks. However, the seemingly routine procedure was accompanied by vociferous opposition from local Christian conservative residents. Marjorie Rogers, a county resident with children in the school system, presented the board with a petition containing over 2300 signatures opposing the science textbooks for advocating "Darwinism, unchallenged". At times, the public testimony prior to the vote became emotionally charged. "God created earth and man in his image", said parent and resident Patricia Fuller. "Leave this garbage out of the textbooks. I don't

want anyone taking care of me in a nursing home some day to think I came from a monkey" (*Atlanta Journal-Constitution* 2002 Mar 29).

Endeavoring to placate the creationists, the board stated that a sticker would be inserted into each textbook that covered the topic of evolution explaining that it is not a fact, only a theory (see RNCSE 2002 May/Jun; 22 [3]: 9). Attorneys were consulted in an attempt to ensure the wording would be constitutional.

The final wording of the sticker 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." The stickers have already been approved and inserted into the textbooks, according to Cobb County teacher Wes McCoy.

Leading the push for creationism in Cobb County was the North Georgia chapter of the American Family Association, which lobbied the school board intensively, initially to reject the proposed textbooks. Later the chapter brought John Calvert and William Harris, both managing directors of the Intelligent Design Network, a Kansas-based organization that promotes "intelligent design", to Cobb County to speak at public events. (According to its mission statement, the American Family Association, founded by Donald Wildmon, "exists to motivate and equip citizens to change the culture to reflect biblical truth". AFA's Ohio chapter sponsors Science Excellence for All Ohioans, the creationist group active in attempting to undermine the treatment of evolution in the proposed Ohio science standards [see RNCSE 2002 Jan-Apr; 22 (1-2): 4-5].)

THE ICR COMES TO COBB COUNTY

On April 29, more than 200 people, including parents and students, attended a lecture on "creation science" at Midway Presbyterian Church, in Powder Springs, Georgia. Institute for Creation Research (ICR) lecturer Mike Riddle presented the case for creation, arguing that many aspects of "Darwinism" have been disproved. Riddle held to the standard anti-evolutionist's line: life is simply too complex to have come into being





by natural processes; therefore God must have created life and guided its development through time. He also rejected common descent and, specifically, the thesis that humans descended with modification from earlier ancestors. According to a story in the *Atlanta Journal-Constitution* (2002 Apr 30), "Monday's lecture was organized in part to educate about the idea [of] creation science, but also to encourage locals to promote a supplement to textbooks that includes theories that Riddle and others said have been excluded from modern education." In attendance was Marjorie Rogers, who presented the Cobb County Board of Education with the pro-creationism petition in March; she was quoted as saying, "This is not about the Bible. It's about science."

THE PRO-EVOLUTION SIDE ORGANIZES

As the local press started to report on the controversy, pro-evolution activists quickly began to organize in response. Scientists from many of the nearby colleges and universities, including Kennesaw State College, Emory University, Georgia State University, and the Georgia Institute of Technology, began circulating inter-departmental letters with signatories from many relevant disciplines affirming support for evolution education and urging the Cobb County Board of Education to exclude faith-based concepts such as "scientific creationism" and "intelligent design" creationism from the science curriculum. These letters were submitted to the Board.

Scientists from Kennesaw State University, initially organized by Ronald H Matson, Professor of Biology and Assistant Chair of the Department of Biological and Physical Sciences, were among the first to circulate such letters. Their petition, dated April 16, 2002, criticized the disclaimer for fostering "a misunderstanding of the role evolution plays in biology", explaining that "Evolution is the major unifying concept that allows biologists to make sense of a very complex world. This disclaimer makes it seem that biologists are not sure of evolution's role in the biological world. This is not true."

Ninety-nine scientists from Emory University signed a letter dated September 9, 2002, that read in part, "[a]s science educators at the gradu-

ate level, we must take a stand against such stickers that call into question scientific, evidence-based instruction in the public schools. We feel that it is our duty as scientists, educators, and citizens to ensure that secondary level science classes teach science and not religion. There is a desperate need for high-quality science education in the United States, Georgia, and in Cobb County. To put evolutionary theory onto the same level as faith-based creationism and 'intelligent

design' would disregard mountains of evidence carefully gathered by thousands of scientists over the past 160 years."

In addition, Bruce Alberts, President of the National Academy of Sciences, wrote a letter to the Georgia members of the NAS, asking them to make their voices heard in support of evolution education by sending e-mails to the Cobb County School Board and by writing op-ed pieces for local and state newspapers.

NSTA's Letter to the Cobb County Board of Education

September 23, 2002

Dear Board Members:

On behalf of the National Science Teachers Association (NSTA) and its 53 000 members and 450 000 chapter members nationwide, we strongly encourage the Board of Education of the Cobb County School District to reject without qualification any policy allowing or encouraging teachers to promote nonscientific viewpoints related to human origins or those which may discourage appropriate and pedagogically valid instruction of evolution. Because evolution is a widely accepted scientific theory and a major unifying theme of biology, NSTA and thousands of scientists and educators worldwide have concluded that evolution — and only evolution — should be taught in science classes.

Students need to understand evolution to be well-educated citizens, as well as to be prepared for college-level science instruction. Cobb County students will be poorly served if they come away from science classes thinking that evolution is a weak scientific theory somehow different from others, which is the likely outcome of the policy under consideration. The inclusion of any religious theories, such as creationism or intelligent design, will only weaken the quality of science instruction, and the students of Cobb County will pay the ultimate price.

In addition, the policy under consideration gives science teachers imprecise and vague directives regarding the teaching of "disputed views". They are instructed only to use "good judgment" and to "take into account the age and maturity level of their students", which teachers already do. Apparently the purpose of the policy statement is to erroneously single out evolution as an especially controversial issue, which misleads students as to the importance of evolution in science.

NSTA urges you to support science teachers in Cobb County so they are able to teach science the way it should be taught. They should not be censored or pressured as they pursue their professional responsibility to provide quality science instruction to help students understand the natural world.

Attached is NSTA's official position paper on The Teaching of Evolution. We would be glad to further discuss this issue with you.

Sincerely,

Dr Gerald Wheeler
Executive Director

The efforts of the supporters of evolution education were not restricted to writing letters, of course. Although no one supporting evolution education spoke at the March 28 board meeting, once the diverse group of scientists, educators, and parents of children in the Cobb school system came together, their presence at the board meetings — and in the media — became constant. While the scientists continually stressed the fact that there is no scientific controversy over evolution, only a political and social one, parents reminded the board members that they had a responsibility to assist them in providing a quality education for their children, one that includes the scientific theory of evolution, and not faith-based concepts.

At the August 8 board meeting, pro-evolution speakers outnumbered creationists by approximately 5 to 1. Speakers included Cobb County parents with children in the public schools system and scientists from Emory University and Kennesaw State University, where many Cobb students go to college.

THE ACLU WEIGHS IN

On August 21, the Georgia chapter of the American Civil Liberties Union (ACLU) filed a complaint in the US District Court in Atlanta against the Cobb County School District, its superintendent, Joseph Redden, and the Cobb County Board of Education, on behalf of Cobb County resident and parent Jeffrey Michael Selman, claiming that the board's disclaimer violates the First and Fourteenth Amendments to the US Constitution. In the complaint, the ACLU argues that because the placement of the stickers was due to complaints against evolution from many parents demanding equal time for creationism, the purpose of the stickers is to advance a particular religious view. Part of its evidence comes from a remark of the vice-chair of the Cobb County Board of Education, Gordon O'Neill, stating the disclaimer is "...relevant to the value that we place on the concept of a Supreme Being and his or her role in the progress of man over time."

As the case against the Cobb disclaimer moves forward, it will undoubtedly draw widespread media attention. NCSE will work with local activists to monitor the situation and keep its members informed.

The "Theories of Origin" Policy

Skip Evans
NCSE Network Project
Director

While the controversy about the textbooks was taking place in Cobb County, Georgia, a parallel controversy about the "Theories of Origin" policy of the Cobb County Board of Education was in the works.

Adopted in December 1979, the policy inappropriately singles out human evolution for special treatment, stating that "some accounts of the origin of the human species as taught in public schools are inconsistent with the family teachings of a significant number of Cobb County citizens." Consequently, the policy requires that the instructional program and curriculum will be planned with these religious objections taken into consideration. The policy closes with the claim that the "[c]onstitutional principle of separation of church and state shall be preserved."

On August 22, 2002, the Cobb County Board of Education voted to replace the 1979 "Theories of Origin" policy; the replacement policy was subjected to a 30-day review period. The new policy read in part:

As stated in Policy IA, Philosophy, it is the educational philosophy of the Cobb County School District to provide a broad based curriculum; therefore, the Cobb County School District believes that discussion of disputed views of academic subjects is a necessary element of providing a balanced education, including the study of *the origin of the species* [emphasis added]. This subject remains an intense area of interest, research, and discussion among scholars. As a result, the study of this subject shall be handled in accordance with this policy and with objectivity and good judgment on the part of teachers, taking into account the age and maturity level of their students.

The purpose of this policy is to foster critical thinking among students, to allow academic freedom consistent with legal requirements, to promote tolerance and acceptance of diversi-

ty of opinion, and to ensure a posture of neutrality toward religion. It is the intent of the Cobb County Board of Education that this policy not be interpreted to restrict the teaching of evolution; to promote or require the teaching of creationism; or to discriminate for or against a particular set of religious beliefs, religion in general, or non-religion.

Although the replacement policy contains appropriate and praiseworthy statements about allowing academic freedom, promoting tolerance, and ensuring a posture of neutrality toward religion, its treatment of evolution is not entirely satisfactory. The first paragraph presents evolution — strangely described as "the origin of the species" — as its sole example of a "disputed view". And while it is certainly true that evolution is a "subject [that] remains an intense area of interest, research, and discussion among scholars", no attempt is made in the statement to clarify that the fact of evolution is not a matter of dispute within the scientific community. Thus the policy as worded is likely to encourage those hostile to evolution education.

The second paragraph at least makes it clear that the policy is "not to be interpreted to restrict the teaching of evolution; [or] to promote or require the teaching of creationism"; unsurprisingly, the restriction was unwelcome to the national office of the American Family Association, which, in an "action alert" dated September 25, decried the policy's "failure to guarantee the biblical account of creation a place at the table." However, the North Georgia chapter of the AFA has been very supportive of the board's action.

The defenders of quality science education in Cobb County would have preferred the statement to state explicitly that it was not intended to "promote or require the teaching of creationism or other faith-based concepts", such as "intelligent design". Debra Power, a Cobb resident and parent, said, "If it's faith-based, or religious-based, which this appears to be, you cannot cater to that and acknowledge the diversity of students we have in our public schools."

In a letter dated September 23, the executive director of the National Science Teachers Association, Gerald Wheeler, wrote directly



to the board, speaking for its 53 000 members and 450 000 nationwide chapter members (see *"NSTA's Letter to the Cobb County Board of Education"*, p 10). He explained to the board that "the policy under consideration gives science teachers imprecise and vague directives regarding the teaching of 'disputed views'. They are instructed only to use 'good judgment' and to 'take into account the age and maturity level of their students', which teachers already do. Apparently the purpose of the policy statement is to erroneously single out evolution as an especially controversial issue, which misleads students as to the importance of evolution in science."

At the board meeting on September 26, the proposed replacement "Theories of Origins" policy was adopted by a vote of 7-0. Despite the national AFA's complaint in its action alert, the anti-evolutionists attending the meeting — many of whom arrived on a bus chartered by the Northern Georgia chapter of the AFA — gave the board a standing ovation. The interpretation of the vote as a victory for creationists was encouraged by the mainstream media, which throughout the controversy seemed unable to grasp what the board was actually proposing, at least in its public comments and written documents. Even after the board issued a press release stating that the proposed policy would not allow the teaching of creationism, headlines such as "Georgia School Board Requires Balance of Evolution and Bible" (*The New York Times* 2002 Aug 23) continued to appear around the country.

Although the vote was not a victory for creationists, it was not a clear victory for supporters of evolution education either. Eugenie C. Scott, the executive director of the National Center for Science Education, commented, "The board is to be commended on its unanimous decision not to present creationism in science classes in Cobb County." "But the board giveth and the board taketh away", Scott added. "Mixed signals are still being sent to teachers and citizens."

In any case, the vote hardly brings the matter to a close. Michael Manely, the ACLU lawyer handling Jeffrey Selman's case, said in the local press the following day that he was considering adding a complaint about the

new policy to the existing complaint against the stickers (see *"Cobb County: A Textbook Case"*, p 9). As of this writing, he has not done so.

As we know from past experience, what matters even more than lawsuits and school board votes is what children are taught in individual classrooms. Fortunately, a very capable group of scientists, parents, and activists has assembled to monitor what repercussions the policy may have in the classrooms of their communities. NCSE will continue to work with them and to keep its members informed as events unfold.

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Evolving Banners at the Discovery Institute

Glenn Branch
NCSE Deputy Director

The original banner of the Discovery Institute's Center for the Renewal of Science and Culture — the institutional home of "intelligent design" creationism — featured the familiar picture from the Sistine Chapel of God touching Adam:

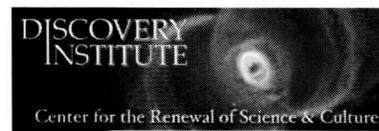


(Banner in place approximately November 1996 - April 1999.)

The image was entirely appropriate, since the Discovery Institute's president, Bruce Chapman, explained that the Center seeks "[t]o replace materialistic explanations with the theistic understanding that nature and human beings are created by God." Adam was subsequently replaced with the double helix of DNA:

(Banner in place approximately October 1999 - August 2001.)

But the explicit religiosity of Michelangelo's image belied the Center's disavowal of any religious motivation, and the banner was eventually replaced. The replacement features a planetary nebula (the MyCn 18 Hourglass Nebula, photographed by the Hubble Space Telescope), which presumably was selected because it happens to resemble a human eye:



(Banner in place approximately October 2001 - August 2002.)

Still present in the name of the Center, however, was the word "Renewal" — a peculiarly inspirational word for the name of a center that seeks (in its own words) to "challenge materialism on specifically scientific grounds." The Center recently removed the word "Renewal" from its name and revised the banner accordingly:

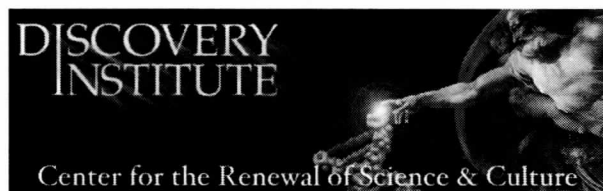


(Banner in place since August 2002.)

So far so good. But because the proponents of "intelligent design" have still not published anything in the peer-reviewed scientific literature that supports their claims, there is still a superfluous word in the Center's name: "Science". We look forward to the next step in its evolution.

POSTSCRIPT

The foregoing exercise in poking fun at the Discovery Institute's Center for (the Renewal of) Science and Culture was posted on NCSE's web site on August 29, 2002. It was summarized, to NCSE's unalloyed delight, in the Random Samples column of *Science* (2002 Sep 20; 297: 1991). The Center's explanation of its change of name may be found at <<http://www.discovery.org/crsc/nameChange.html>>.



Brooks on “Intelligent Design”

Rodney Brooks, the director of the Artificial Intelligence Laboratory at the Massachusetts Institute of Technology and the author of *Flesh and Machines: How Robots Will Change Us* (New York: Pantheon, 2002), was interviewed on the Science Friday program of National Public Radio on August 30, 2002.

About 39 minutes into the 47-minute program, a caller, Carl from Los Angeles, commented, “Seeing that both of you folks are basically at the top of your industry and your research, and by way of — as I was listening and asked, dealt with that question — basically how you develop this, uh, the insect through a reverse engineering method, how is that affected by way of ‘intelligent design’, your opinion over the discussion or controversy of creationism versus evolution, and how that all plays out in what you’ve found in your development and in your research.”

Brooks responded, “Yeah, I don’t see any controversy there at all. When we build our artificial evolution systems, we very quickly get things evolving that we couldn’t imagine evolving, and most of these are purely inside computers, although these days people are starting to connect them up and produce physical robots out of them. And the mechanism of evolution works fantastically well and surprisingly well, and I’m awed by how quickly you get designs coming from these random processes with — when you have some selective force there. So for me if anything although looking at an insect and how complex it is, building an artificial evolution system just to me indicates just how easy it is.”

Incidentally, Brooks is evidently no stranger to the creationism/evolution debate. Appearing on the frequently-asked questions section of his web site <<http://www.ai.mit.edu/people/brooks/faq.shtml>> is the question “Some of your papers refer to evolution. Don’t you know that evolution is a myth?” Brooks replies:

If you believe that then you must reject most of modern science, all of modern biology, most of medicine, and large

amounts of technology that are used to produce the food you eat every day.

You may as well try to tell me that the world is flat. It’s an equally preposterous claim. I will not respond to you if you send me email, telephone me, or fax me about this. Life is too short.

Brooks was also among the scientists whose work was cited and misrepresented in the Discovery Institute’s “Bibliography of Supplementary Resources for Ohio Science Instruction” (see *RNCSE 2002 Jul/Aug; 22 [4]: 15–8, 23*).

[The original program is archived at the NPR web site <www.npr.org> in RealOne format and may be listened to with the free RealOne Player.]

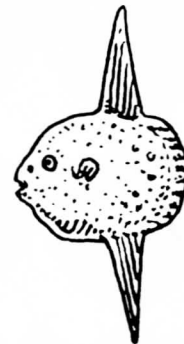
The *Evolution* Backlash Continues

Glenn Branch
NCSE Deputy Director

A further, if belated, attack on the PBS *Evolution* series appeared in *Touchstone* (2002 Jun; 15 [5]: 21; available at <<http://www.touchstonemag.com/docs/issues/15.5docs/15-5pg21.html>>). Peter J. Leithart, identified as an ordained minister in the Presbyterian Church in America who teaches theology and literature at New St Andrews College in Moscow, Idaho, contended that “As a theory about the origin and development of all species, [“Darwinism”] must not only provide evidence of the development of ‘new species’ in the narrow technical sense, but of the development of new families and genres [sic]. Not a scrap of evidence for change of this magnitude was presented on the program.” Citing Phillip Johnson, Leithart argued that only a prior philosophical commitment to naturalism on the part of scientists can explain their adherence to evolution. He concluded, “*Evolution* has provided further evidence of the metaphysical character of Darwinism, has made the vacuity of the broad claims of evolution plain to a large audience, and has demonstrated that, as a theory about

the origin of species, evolution has little going for it beyond massive public funding, most of the prestige university posts, and, especially, ‘way-cool’ computer graphics.” *Touchstone* — “A Journal of Mere Christianity” — has a history of publishing articles endorsing “intelligent design”: Phillip Johnson has a regular column (“The Leading Edge”) in the magazine, and most of the articles in the “intelligent design” anthology *Signs of Intelligence*, edited by William Dembski and James Kushiner (Grand Rapids [MI]: Brazos Press, 2001) originally appeared in *Touchstone* 1999 Jul/Aug; 12 (4).

For a lengthy survey of the reactions of creationists and other ideological opponents of evolution to the *Evolution* series, see *RNCSE* 2001 Sep-Dec; 21 (5–6): 5–14.



ERRATUM: AMINO ACID TERMINI

In an attempt to simplify the discussion on the structure of amino acids, we went a little too far (see “Genetic evidence of body-plan macromutation”, *RNCSE 2002 May/Jun; 22 [3]: 29*). Several astute readers wrote in to point out the editor’s gaffe in referring to the “C-terminus” of an amino acid as the “carbon end”. Among others, member Michael Buratovich wrote:

Proteins are biopolymers of amino acids that are linked together by peptide bonds, which are highly directional linkages consisting of bonds between the amino group of one amino acid and the carboxyl group of another. The entire is constructed in this fashion and is highly directional in its arrangement and had one end with a free amino group (the amino terminus) and another end with a free carboxyl group (the carboxyl terminus). I liken it to a train that has an engine at the front (the amino terminus) and the caboose at the end (the carboxyl terminus).

And that may be why your humble editor only managed an A- in organic chemistry.

[Thanks to Dr Michael Buratovich and numerous others who wrote in to correct this error.]

UPDATES

Denmark: The incoming chair of the Christian People's Party (Kristelig Folkeparti), Marianne Karlsmose, reportedly proposed that biblical creationism be taught alongside evolution in Danish schools. The *Berlingske Tidende* newspaper regards the proposal as a sign that "fundamentalism is growing as an underlying tendency and it isn't only found in small closed Christian sects, nor is it something which Islamic movements hold the patent on", adding that "If you want a clearer Christian basis for all teaching you can send your children to independent school. But the first book of Moses, or other religious accounts of the Creation for that matter, are not relevant as theories of natural science" (quoted in the European Press Review section of the BBC World Service, 2002 Oct 23, available on-line at <<http://news.bbc.co.uk/1/hi/world/europe/2351897.stm>>). The chair of the Danish Teachers' association, Anders Bondo Christensen, said that Karlsmose's proposal was inappropriate: "The subject of biology will include the instruction of scientific knowledge, which includes Darwin, while Christian beliefs should be limited to Christian theory or other religious courses" (*Copenhagen Post* 2002 Oct 24; available on-line at <<http://cphpost.periskop.dk/default.asp?id=25516>>). NCSE members in Denmark regard the proposal as a publicity stunt rather than a serious proposal.

Florida, Pensacola: Kent Hovind, the founder of Creation Science Evangelism, was arrested on August 15, 2002, according to the *Pensacola News Journal* (2002 Aug 17). The charges were assault, battery, and burglary; the burglary charge was originally a second-degree felony charge, but was later upgraded to a first-degree felony charge, since the alleged burglary involved assault and/or battery. On December 9, the day on which his trial was originally scheduled to begin, the charges were dropped.

Indiana, Terre Haute: On September 23, 2002, at Indiana

State University, creation evangelist Kent Hovind debated evolution with ISU professor and NCSE member George Bakken. Hovind, whose supporters came from as far away as Tennessee, put on his usual show, which one attendee described as exhibiting "a proclivity for slander, bombast, and raw demagoguery". Bakken argued that evolution is of a piece with the rest of science, drawing parallels between Newton's theory of gravity and Darwin's theory of evolution, and recommended the familiar maxim that "The Bible tells us how to go to heaven, not how the heavens go". He also explained that the idea of such a debate is in itself problematic, since it suggests, falsely, that Hovind is qualified to speak on the subject, that scientific disputes are to be resolved by debates in a public forum, and that the audience is capable of judging the merits of the debaters' claims about science; Hovind responded by telling the audience that Bakken evidently regarded it as stupid. In addition to explaining evolution, Bakken also directly attacked Hovind's credentials (see RNCSE 1999 Sep/Oct; 19 [5]: 28-30 for Barbara Forrest's discussion) and — after Hovind described biologists as liars and charlatans — his character: at the end of the debate, to Hovind's apparent discomfort, he invited the audience to consider Hovind's recent arrest on charges of assault, battery, and burglary (see Florida, Pensacola, paragraph above); the crowd was reportedly unimpressed. For reports of the debate, see the ISU student newspaper, the *Indiana Statesman* (2002 Sep 25; <http://www.indianastatesman.com/vnews/display.v/ART/2002/09/25/3d91c201bd0f6?in_archive=1> and the *Terre Haute Tribune Star* (2002 Sep 24; <<http://www.tribstar.com/archives/index.inn?loc=detail&doc=/2002/September/24-3778-news01.txt>>). A letter by Bakken discussing the debate appeared in the *Indiana Statesman* (2002 Sep 30; <http://www.indianastatesman.com/vnews/display.v/ART/2002/09/30/3d98551543e7a?in_archive=1>).

Iowa, Des Moines: The Interfaith Alliance of Iowa sent a questionnaire to the candidates for school board in Des Moines, West Des Moines, and southeast Polk County to ask about their position on various church/state issues, including whether they support the teaching of biblical creationism in science classrooms. Mary Ann Spicer and Nadine Hogate, running in Des Moines, and John Ambrosion and Mark Patterson, running in West Des Moines, all indicated that they indeed supported the teaching of creationism, according to the *Des Moines Register* (2002 Sep 7). In the September 10, 2002, election, all but Ambrosion were defeated.

Kansas: Following the November 5, 2002, elections, the Kansas state board of education is likely to be evenly divided, 5-5, on evolution education. The decisive contest was in District 7, where Democrat L Duane Anstine, a supporter of evolution education, was defeated by Republican Kenneth Willard. According to the *Wichita Eagle* (2002 Nov 6; available on-line at <<http://www.kansas.com/mld/kansas/news/local/4454357.htm>>), Willard "says macroevolution should be taught but that students also should learn scientific evidence that contradicts it. Both should be included in the science standards established by the state board." Two incumbent members of the board who were defeated in the primary election (see RNCSE 2002 Jul/Aug; 22 [4]: 8), Sonny Rundell and Val DeFever, ran unsuccessfully as write-in candidates in Districts 5 and 9, respectively; both were also supporters of evolution education.

Nebraska: Two anti-evolutionists on the Nebraska Board of Education were narrowly defeated in the November 5, 2002, election. In District 8, Kathryn C Piller was defeated by Joe Higgins by 515 votes; in District 7, Kathy Wilmot was defeated by Kandy Imes by only 124 votes, a margin so narrow that a recount may be necessary, according to the *Grand Island Independent* (2002 Nov 6; on-line at <<http://www.theindependent.com>>).



com/stories/110602/new_boardofed06.shtml>). In the summer of 2002, both Piller and Wilmot unsuccessfully attempted to ensure that the newly drafted state science standards reflected the provisions of the so-called Santorum Amendment (see RNCSE 2002 May/Jun; 22 [3]: 4-5).

New Hampshire, Hanover: On October 8, 2002, Jerry Swift, who described himself as the Discovery Institute's field representative for New England, showed the "intelligent design" videotape *Unlocking the Mystery of Life* at Dartmouth Medical School. About 15 people, almost all medical students or graduate students, watched the videotape and participated in the following discussion, in which a number of skeptical questions were reportedly asked: Why was out-of-date science presented in the video? What was the justification for the video's claim that DNA is the only possible carrier of information? Is "intelligent design" falsifiable, and if not, is it genuinely science? NCSE member Niles Donegan, who attended, chatted afterwards with Swift, who said that he volunteered to be the (unpaid) New England field representative for the Discovery Institute after attending its 2000 meeting at Yale; as such, Swift explained, he helped to bring Michael Behe, Paul Nelson, and Jonathan Wells to speak at various colleges and universities throughout New England.

New Mexico: In a press release dated July 23, 2002, the "intelligent design" grassroots organization Intelligent Design Network ("IDnet"), headquartered in Shawnee Mission, Kansas, announced the formation of Intelligent Design Network of New Mexico (<<http://www.intelligent-design-network.org/PressReleaseNewMexico.htm>>). IDnet, whose managing director is John Calvert, was — and is still — active in promoting "intelligent design" not only in its home state of Kansas but also in Ohio. (Jody Sjogren, who illustrated Jonathan Wells's *Icons of Evolution*, is the managing director of IDnet of

Ohio.) The executive director of IDnet of New Mexico is Joseph D Renick, a mechanical engineer employed by Northrop Grumman. NCSE member Dave Thomas, the president of New Mexicans for Science and Reason, comments, "With recent visits by Phillip Johnson, William Dembski, and Michael Behe, it appears the ID movement is making plans to hobble science education in the Land of Enchantment."

Tennessee: According to a story in *The (Nashville) Tennessean* (2002 Oct 6), "[t]he evolution-creationism debate that was raging the previous time Tennessee educators picked new science textbooks seems to have taken a breather this time." In Tennessee, local school districts cannot use state funds to pay for textbooks that are not approved by the State board of Education. When the State Textbook Commission met in November 1996 to consider K-12 science textbooks to recommend for approval, one of the commissioners presented a lengthy creationist litany of supposed inaccuracies in the candidate textbooks, and another submitted a memorandum proposing that the commission require textbooks to include a version of the Alabama disclaimer (see NCSE Reports 1996 Winter; 16 [4]: 7). In the 2002 process, however, nothing comparable occurred. State science consultant Linda Jordan was quoted by *The Tennessean* as saying, "[Evolution is] in the standards; it's expected it'll be taught. So far we've not had anyone raise any major issues about it."

Texas: Before the primary elections on March 11, 2002, the Texas Freedom Network, which describes itself as "a mainstream voice to counter the religious right", sent a questionnaire to the candidates for the Texas State Board of Education that included the question, "Do you support teaching biblical creationism as an alternative to evolution in the science curricula?" Those who answered "yes" (or who, on the basis of their voting record and their public statements, were deemed likely to support teaching

ERRATUM: SNAIL DARTER

In RNCSE 2002 Jan-Apr; 22 (1-2): 52, we mistakenly cited the snail darter (*Percina tanasi*) in a passage about mainland birds. As member William D Anderson Jr pointed out, the snail darter "is a species of freshwater fish known from eastern Tennessee, northeastern Alabama, and extreme north Georgia. Its conservation status has been much in the news for the past 20 or 25 years."

Of course, we *now* remember the snail darter as an endangered *fish* species important in controversies over the development of hydroelectric power and water usage at least as far back as the Carter administration. We apologize for the error and thank Dr Anderson for sending in the correction.

creationism) are Trini Munoz (R, district 1), David Bradley (R, incumbent in district 7), Jason W Ceyanes Sr (R, district 7), Patricia "Pat" Harper (R, district 9), Cynthia A Thornton (R, incumbent in district 10), Warren Norred (R, district 11), Mavis Best Knight (D, district 13), Lynn Edward Allen (R, district 14), Bob Craig (R, district 15), and David Schaeffer (D, district 15). Ceyanes, Harper, Norred, and Allen were defeated in the primary election. In the November 5 election, Munoz and Schaeffer were defeated, Bradley and Thornton were re-elected, and Knight (who ran unopposed) and Craig were elected. For the complete questionnaire and results, see <<http://www.tfn.org/issues/voterguides/sboe02.html>>.

[NCSE thanks George Bakken, Jason Bobe, Niles Donegan, J Richard Schrock, Hans Henrik Staerfeldt, Fedor Steeman, Jim Swan, Dave Thomas, and David Wayne Ussery for information used in this article.]



NCSE NEWS

News from the Membership

Glenn Branch
NCSE Deputy Director

From time to time we like to report on what our members are doing. As the following list shows, they have a lot to be proud about!



Philip Appleman's abridgement of *The Origin of Species* was released (New York: WW Norton, 2002); it contains excerpts from the introduction and chapters 1, 2, 3, 4, 6, 9, 13, and 14 of the first edition of the *Origin*, along with Appleman's introduction and a bibliography. In his introduction, Appleman writes, "Although the arguments of the creationists are intellectually frivolous, they are being promoted with evangelical fervor and often have serious political and educational consequences. ... The sad fact is that many thousands of young people, even today, are still being denied a sound education in biology as a result of creationist political pressures" (pages 19, 21). Appleman is Distinguished Professor Emeritus at Indiana University and the editor of *Darwin: A Norton Critical Reader*, third edition (New York: WW Norton, 2001).

The Antiquity of Man: Artifactual, Fossil and Gene Records Explored (Frederick [MD]: PublishAmerica, 2002), a book by **Michael Brass** that critically examines Michael Cremo and Richard Thompson's Hindu-inspired creationism, is now available. From the publisher's web site (<<http://www.publishamerica.com>>): "Palaeo-anthropology and archaeology are fascinating, vibrant, and multi-disciplinary areas of research encompassing everything from isotopic laboratory work to down-and-dirty hands-on excavation. The discipline has grown tremendously since the time of Darwin and continues to yield new important revelations with each passing year. Recently a new variant of creationism has arisen to challenge evolution: Hindu creationism, as advanced by its most prominent proponents Michael Cremo and Richard

Thompson. *The Antiquity of Man* explores the basic tenets that run through all fundamentalist writings. It is the only published work to provide an in-depth critique of Cremo and Thompson's work, and to examine creationism from the perspective of palaeoanthropology and archaeology: the application of genetics, our relationship with archaic hominins and chimpanzees, and the origins of modern human behavior." Also, Brass's article "Tracing Graham Hancock's shifting cataclysm" — which debunks specific pseudoscientific claims about "Earth Crustal Displacement", the climates and fauna of Siberia and Alaska, and the deaths of the mammoths made by Hancock in his book *Fingerprints of the Gods* — appeared in *Skeptical Inquirer* (2002 Jul/Aug; 26 [4]: 45-9). For further information on Brass's work, see his web site at <<http://www.antiquityofman.com>>.

Taner Edis's *The Ghost in the Machine: God in Light of Modern Science* (Amherst [NY]: Prometheus, 2002) is now available. The publisher writes, "Is there a God, or a spiritual reality beyond nature? Physicist Taner Edis takes a fresh look at this age-old question, focusing on what we have learned about our world rather than on traditional metaphysical disputes. Emphasizing a search for explanation rather than listing flaws in theistic metaphysics, Edis uses the results of natural science to present a world where complexity, intelligence, and even the sublime heights of religious experience emerge from what is ultimately material and random. Sympathetically criticizing Muslim and New Age perspectives, as well as Jewish and Christian arguments, Edis argues that a thoroughgoing naturalism leads to a much better explanation of our world. While making it clear that spiritual views have a genuine intellectual appeal, Edis systematically critiques such arguments, contrasting them with stronger naturalistic explanations. Science is central to this naturalistic picture; modern physics, evolutionary biology, and critical history, as well as contemporary psychology and brain sciences, all cast doubt on any spiritual reality. Bringing together ideas from many

disciplines in a style that remains accessible to nonspecialists, and also interesting to scientists and philosophers, Edis provides an informative, in-depth statement of the case for scientific naturalism as the most accurate and powerful description of our world today." Edis is Assistant Professor of Physics at Truman State University; his last contribution to *RNCSE* was "Cloning creationism in Turkey", *RNCSE* 1999 Nov/Dec; 19 (6): 30-5.

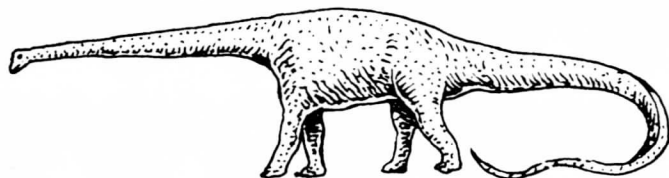
David Greenwood, who teaches English at Wilkes Community College in Wilkesboro, North Carolina, responded to a creationist's contention in the *Winston-Salem Journal* (2002 Apr 29) that science is limited to the actually observed, writing, "Actually, scientific fact is often inferred from observable evidence of what happened in the past", and adducing examples from archaeology, geology, and biology (2002 May 21). Also, in response to the creationist's claim that the human eye is "evidence of perfect design", Greenwood ended his letter with the trenchant question, "why have I had to wear glasses all my life?"

Andrew O Lutes wrote to the *Mansfield, Ohio, News-Journal* (2002 May 19) to rehearse the evidential basis of evolution, explaining that "Evolution isn't taken on faith. There's nothing religious about it. It isn't a matter of opinion. It doesn't require any miracles. The evidential facts plainly show evolution." In contrast, he continued, "'intelligent design' and other anti-scientific notions deserve no place in education." In a later issue of the *News-Journal* (2002 Jun 27), Lutes castigated two creationists who had quoted Darwin out of context on the evolution of the eye and on the need to consider "both sides" in scientific disputes, explaining that "it takes no faith to accept evolution, and it's 'intelligent design', not evolution, that's being 'exposed for the bankrupt fraud that it is.'"

Also in the *Mansfield, Ohio, News-Journal* (2002 May 28), **Jeffrey K McKee**, Professor of Anthropology at the Ohio State University and author of *The Riddled Chain* (New Brunswick [NJ]: Rutgers University

Press, 2000), wrote to add his words "in support of a state science curriculum that must include the teaching [of] evolutionary theory ... and not pseudoscientific alternatives." Lamenting the fact that his education in Mansfield's schools was devoid of evolution, McKee went on to say that evolution, unlike creation science and "intelligent design", "is the best that science has to offer, and has withstood every test so far."

On June 10, 2002, the science-religion web site *Meta* posted a response by **Paul A Lucas** to Jeff W Dahms's "Science, religion, evolution, and creation — a phylogeny" (*Meta* 2002 June 7). Referring to the perennial creation-evolution controversy, Lucas wrote, "I see the problem arising from a failure to teach the philosophy of science: what science is, why it does what it does, how it investigates the universe, and the limitations of science." He went on to criticize Dahms for characterizing methodological naturalism as a "rule" of science; it is, rather, a consequence of the experimental method. Citing a passage from Bishop Joseph Butler quoted by Darwin, Lucas also argued that there are theological reasons to accept methodological naturalism, concluding,



ing, "The scientist simply discovers the material method by which deity works and believes that the material method will not work unless continually supported and sustained by the supernatural. There is no dichotomy: the material process, including evolution, is simply deity at work. All that is necessary is discarding a god-of-the-gaps theology that is not supported by either science or theology."

Jonathan Marks's *What It Means to be 98% Chimpanzee* (Berkeley: University of California Press, 2002) was reviewed by Micaela di Leonardo in *The Nation* (2002 Jul 8; 275 [2]: 27-30). Di Leonardo opened by saying that the death of Stephen Jay Gould leaves a void in English-language popular science writing, and then adding "But molecular anthropologist Jonathan Marks, with his broad history-of-science background,

his take-no-prisoners stance on scientific stupidity and overreaching, and his hilarious Groucho Marx delivery, can help to fill that void." She praises Marks's book as "a real treasure trove ... an important and refreshing book". (See *Andrew J Petto's review of What It Means to be 98% Chimpanzee in RNCSE 2002 May/Jun; 22 [3]: 35-7.*)

Ernst Mayr's *What Evolution Is* was published by Basic Books (New York: 2001). The reviewer for *Publishers Weekly* writes, "No one but Mayr could explain evolution so well, and though the text is peppered with many scientific terms, overall the author is triumphant in his goal to teach 'first and foremost ... biologist or not, [anyone] who simply wants to know more about evolution.'" Mayr is Professor Emeritus in the Zoology Department of Harvard University.

Adrian Melott's article "Intelligent design is creationism in a cheap tuxedo" (which borrows its title from **Leonard Krishtalka's** memorable phrase) appeared in the June 2002 issue of *Physics Today*, alongside **Mano Singham's** "Philosophy is essential to the intelligent design debate". Melott, who is Professor of Physics and Astronomy at the University of Kansas, writes,

"Hired-gun 'design theorists' in cheap tuxedos have met with some success in getting close to their target: public science education. I hope to convince you that this threat is worth paying attention to. As I write, intelligent design (ID) is a hot issue in the states of Washington and Ohio ... Evolutionary biology is ID's primary target, but geology and physics are within its blast zone." Both his article and Singham's are available on-line at <<http://www.aip.org/pt/vol-55/iss-6/p48.html>>.

Following Kent Hovind's June 7, 2002, appearance in Lyndonville, New York, **Lee Minier** wrote to the *Medina Journal-Register* (12 Jun 2002) to discuss his qualifications, noting that "A close examination of his true credentials might lead the reader to a somewhat different assessment of his academic background."

(Readers will remember the expose of Hovind from *RNCSE* 1999 Sep/Oct; 19 [5]: 28-30, in which **Barbara Forrest** explained that his MA and PhD are from Patriot University, a faculty-free degree mill located in a split-level house in Alamosa, Colorado.) Minier also invited the reader to inspect Hovind's web site <<http://www.drdino.com>> to "read some of the inane pseudo-scientific statements made there, as well as his attacks on public education." Subsequently, Minier reports, several members of the local clergy were complimentary about the letter.

NCSE Executive Director **Eugenie C Scott** and Deputy Director **Glenn Branch** collaborated on "'Intelligent design' not accepted by most scientists", a guest viewpoint article that was published in *School Board News*, a publication of the National School Boards Association (2002 Jul 2; 22 [10]: 3, 5). Scott and Branch reviewed the state of play in the debate over "intelligent design" (ID), noting that neither William Dembski's "design inference" nor Michael Behe's "irreducible complexity" is used in scientific research, and explaining that the ID movement is essentially a religious project. "[P]roposals to introduce ID into curricula", they recommended, "should be met with polite but firm explanations that there is as yet no scientific evidence in favor of ID, that ID supporters are wrong to allege that evolution is intrinsically antireligious, and that the sectarian orientation of ID renders it unsuitable for constitutional reasons."

Animals and Science: A Guide to the Debates, edited by **Niall Shanks**, Professor of Philosophy at Eastern Tennessee State University and a coauthor of "Of mousetraps and men: Behe on biochemistry" (*RNCSE* 2000 Jan-Apr; 20 [1-2]: 25-30), was published (Santa Barbara [CA]: ABC-CLIO, 2002). The publisher writes, "*Animals and Science: A Guide to the Debates* explores in depth the relationship between humans and animals. It looks at how science has benefited by the use of animal research, examines how the scientific study of animals has changed our understanding of their place in nature, and charts the consequences of scientific and technological advances for humans and animals. Surveying the entire human/animal relationship since the beginning of recorded history, the book focuses on subjects that range from Plato's and St



Augustine's understanding of animals to the views of PETA and other present-day animal organizations and activists."

Margaret Towne is the new co-editor (with David Fisher) of the *Newsletter of the American Scientific Affiliation & Canadian Scientific & Christian Affiliation*, as reported in a recent issue (2002 Jul/Aug; 44 [4]: 1, 3) of the *Newsletter*. Towne teaches at the University of Nevada, Las Vegas, where she teaches both critical thinking in the philosophy department and microbiology in the biology department; she was a distinguished visiting professor in science and religion at Juniata College in Huntingdon, Pennsylvania, from January 1999 to June 2001. Towne reports that as co-editor of the *Newsletter*, she hopes to keep the ASA membership informed about current events, publications, and issues in science and faith.

[Publications, achievements, honors? Tell RNCSE so we can pass on the good news to all of our members. Call, write, or e-mail.]

NCSE Supporter Presides at Bennett College

Andrew J Petto
NCSE Editor

Those of us who had the privilege of knowing Dr Johnetta B Cole in her long and productive academic career agree that her commitment to good education and outstanding scholarship derive from a passion and dedication that we deeply respect and appreciate. There are many adjectives we could use to describe this long-time Supporter of NCSE — but "retiring" is not one of them. So, we are pleased — but not surprised — to learn that Cole has agreed to come out of retirement to serve as president of Bennett College in Greensboro, North Carolina.

In accepting her presidential appointment, Cole remarked:

Only the challenge to help Bennett College soar to the

heights of its possibility could have brought me out of retirement. I have long admired this fine institution, which is one of only two historically Black institutions of higher learning for women in the United States. Bennett College must be treasured and we all have the responsibility to nurture, invest in and protect her.

In addition to her support of NCSE and its mission, Cole has had an illustrious academic career. She made history in 1987 by becoming the first African American woman to serve as president of Spelman College and became widely known as "America's Sister President". Under her leadership, Spelman became the first historically black college or university to receive a number one rating by *US News and World Report* when the college was named the number one liberal arts college in the South.

After a decade at Spelman, Cole was appointed Presidential Distinguished Professor of Anthropology, Women's Studies, and African American Studies at Emory University in Atlanta; she retired in 2001.

All of us at NCSE applaud Johnetta Cole's dedication and passion for education and wish her the best in her new position.

[See the official Bennett College press release at <<http://www.bennett.edu/jbc/jbcrelease.htm>>.]

Evolution Education Award for Steve Randak

We are pleased to report that the recipient of the first annual National Association of Biology Teachers (NABT) Evolution Education Award is NCSE member Steve Randak, author of "The Children's Crusade for Creationism" (*RNCSE* 2001 Jan-Apr; 21 [1-2]: 27-8) and a voice for teaching evolution featured in the PBS series *Evolution*. Applicants were screened by a panel of judges looking for innovative and effective teaching, professional sharing, and community education efforts to promote accurate understanding of biological evolu-

tion. The award is generously sponsored by The Foundation for the Future of Bellevue, Washington, and includes a \$1000 cash prize, up to \$1000 for travel expenses to the NABT national convention, and a complimentary membership to NABT.

Randak has been teaching since 1967. In those years, he has distinguished himself in all the aspects used as criteria for the award. He has designed a highly successful curriculum, beginning with 4 weeks on the nature of science and deeply infused with evolution. He has created and adapted numerous classroom lessons and activities that effectively teach those topics. Some of those lessons became a part of the ENSI (Evolution and the Nature of Science Institutes) project, and are included in the ENSI web site. He actively participated in the second year of ENSI summer workshops, then became an active Lead Teacher, teaching the program in 7 Satellite ENSIs (SENSIs), reaching perhaps 150-200 teachers directly. He continues to create new lessons; his most popular recent contribution is "Footsteps in Time: Analyzing the Laetoli Trackways".

In addition, he has presented popular evolution workshops at many NABT and NSTA (National Science Teachers Association) conventions over the past 20 years. He has published articles in various journals relating to evolution teaching. One of his most notable innovations was his "historic role-playing": preparing, dressing, and presenting himself to his classes as prominent scientists from the past, including the role of Charles Darwin. He shared his passion and his techniques in an article for *The American Biology Teacher*. These efforts have garnered international interest.

In spite of his efforts (or perhaps because of his effectiveness), he and his colleagues were confronted with a mass student and community effort to include creationism in the district biology courses. A report on this confrontation, and how well it was handled, was included in the landmark WGBH/PBS series *Evolution*.

Congratulations to Steve from all of us at NCSE.

THE GEOLOGICAL SOCIETY OF AMERICA

Statement on Evolution

The Geological Society of America recognizes that the evolution of life stands as one of the central concepts of modern science. Research in numerous fields of science during the past two centuries has produced an increasingly detailed picture of how life has evolved on earth.

The rock record is a treasure trove of fossils, and by 1841, eighteen years before Charles Darwin published *On the Origin of Species*, geologists had not only assembled much of the geologic time scale from physical relationships among bodies of rock, but they had also recognized that fossils document profound changes in life throughout earth's history. Darwin showed that biological evolution provides an explanation for these changes. Since the time of Darwin, geologists have continued to uncover details of life's history, and biologists have continued to elucidate the process of evolution. Thus, our understanding of life's evolution has expanded through diverse kinds of research, much of it in fields unknown to Darwin such as genetics, biochemistry, and micropaleontology. In short, the concept of organic evolution has not only withstood the test of time — the ultimate test of any scientific construct — but it has been greatly enriched.

In recent years, certain individuals motivated by religious views have mounted an attack on evolution. This group favors what it calls "creation science", which is not really science at all because it invokes supernatural phenomena. Science, in contrast, is based on observations of the natural world. All beliefs that entail supernatural creation, including the idea known as intelligent design, fall within the domain of religion rather than science. For this reason, they must be excluded from science courses in our public schools.

This separation of domains does not mean that science and religion are fundamentally incompatible. Many scientists who conduct research on the evolution of life are religious, and many major religions formally accept the importance of biological evolution.

Misinterpreting the Bible's creation narratives as scientific statements, many creationists go so far as to attack the validity of geologic time — time that extends back billions of years. "Deep time" is the foundation of modern geology. It was actually well established, though not quantified, by geologists decades before Darwin published his ideas or most scientists came to accept evolution as the explanation for the history of life. Furthermore, thousands of geologists employing many new modes of research refined the geologic time scale during the twentieth century. Near the start of that century, the discovery of naturally occurring radioactive substances provided clocks for measuring actual ages for segments of the geologic record. Today, some billion-

year-old rocks can be dated with a precision of less than a tenth of one percent. Moreover, modern geologists can identify particular environments where sediments that are now rocks accumulated hundreds of millions of years ago: margins of ancient oceans where tides rose and fell, valley floors across which rivers meandered back and forth, and ancient reefs that grew to thicknesses of hundreds of meters but were built by organisms that could not have grown faster than a few millimeters a year. By studying the fossil record that forms part of this rich archive of earth's history, paleontologists continue to uncover details of the long and complex history of life.

Acceptance of deep time is not confined to academic science. If commercial geologists could find more fossil fuel by interpreting the rock record as having resulted from a single flood or otherwise encompassing no more than a few thousand years, they would surely accept this unconventional view, but they do not. In fact, these profit-oriented geologists have joined with academic researchers in refining the standard geologic time scale and bringing to light the details of deep earth history.

Modern studies of the evolution of earth and its life are not only aiding us in the search for natural resources, but also helping us to understand how the earth-life system functions. Annual layers of ice in the Greenland glacier, for example, range back more than a hundred thousand years. These ice records warn that earth's climate may change with devastating speed in the future. The geologic record also reveals how various forms of life have responded to past environmental change, sometimes migrating, sometimes evolving, and sometimes becoming extinct. In the present world, bacteria are now evolving rapidly in ways that render antibiotics ineffective; to respond to bacterial evolution, we must understand evolution in general.

The immensity of geologic time and the evolutionary origin of species are concepts that pervade modern geology and biology. These concepts must therefore be central themes of science courses in public schools; creationist ideas have no place in these courses because they are based on religion rather than science. Without knowledge of deep time and the evolution of life, students will not understand where they and their world have come from, and they will lack valuable insight for making decisions about the future of their species and its environment.

Contributors: Steven M Stanley (chair), Patricia Kelley, Richard Bambach, George Fisher, James Skehan, Don Wise, and David Dunn.

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ROCK OF AGES; AGES OF ROCK

With the focus of “intelligent design” firmly on biochemistry, information theory, and the origin of life, it is sometimes difficult to remember that there are people who think that isotopic age determination is unreliable, that the Grand Canyon was formed virtually overnight, that strata are dated by fossils and fossils by strata, that the earth is less than 10 000 years old, and, in general, that modern geology is all wrong. To discover or rediscover the delights of geology — and, perhaps, to equip yourself for whatever the latest creationist misinformation about geology will be — check out the following books, all of which are now available through the NCSE web site: <www.ncseweb.org/bookstore.asp>. And remember, every purchase through the web site benefits NCSE!



Illustration by
Dave Smith, used with permission
of the University of California
Museum of Paleontology.

FOR THE GENERAL READER

Pioneers of Geology: Discovering Earth's Secrets

by Margaret W Carruthers and Susan Clinton

Suitable for budding geologists in 5th through 9th grades, *Pioneers of Geology* engagingly presents the history of geology by concentrating on the life and works of 6 important geologists: James Hutton, Charles Lyell, GK Gilbert, Alfred Wegener, Harry Hess, and Gene Shoemaker (who not only codiscovered the comet Shoemaker-Levy 9, but also is widely considered the father of planetary geology). With black-and-white illustrations and photographs; a geological time scale and a diagram of the age and structure of the earth appear in appendices, along with a helpful glossary and a bibliography including references to internet resources.

Annals of the Former World by John A McPhee

Assembled together in *Annals of the Former World* are no fewer than 4 of John McPhee's acclaimed popular books about North American geology — *Basin and Range*, *In Suspect Terrain*, *Rising from the Plains*, *Assembling California* — as well as the previously unpublished *Crossing the*

Craton. Writing in *The New York Review of Books*, Stephen Jay Gould praised McPhee's “ability to capture the essence of a complex issue ... in a well-turned phrase.” McPhee, a staff writer for *The New Yorker* since 1965, won the 1999 Pulitzer Prize for Nonfiction for *Annals of the Former World*.

The Mysteries of Terra Firma: Exploring the Age and Evolution of the World

by James Lawrence Powell

In *The Mysteries of Terra Firma*, Powell — the author of *Night Comes to the Cretaceous* and the president and director of the Los Angeles County Museum of Natural History — describes the development of our understanding of the history of the earth by focusing on 3 themes: Time, Drift, and Chance. For a lucid explanation of the dating techniques used to establish the age of the earth, the revolution wrought by Wegener's theory of continental drift, and the role played by chance asteroid impacts in the history of the earth, look no further. “An accessible, lively account of the biggest questions in earth history”, writes the reviewer for *Booklist*.

Earthsteps: A Rock's Journey Through Time

by Diane Nelson Spickert
illustrated by Marianne D Wallace

Is the 250-million-year career of a rock a suitable subject for a picture book aimed at kindergarteners through 3rd-graders? Yes! Writes the reviewer for *The Children's Bookwatch*, “Marianne Wallace's artwork is nothing short of spectacular. Diane Spickert's narrative text is absolutely faithful to the geology and paleontology of the earth's record as recorded by fossils. *Earthsteps* is a ‘must’ for personal, school and community library children's science books and non-fiction picture book collections.” Complemented with a geological time scale (from the Permian to the Holocene) and a glossary of geological terms.

WHEN AND WHERE

The Age of the Earth

by G Brent Dalrymple

The Age of the Earth begins with a plain answer: “Four and one-half billion years.” But keep reading! Dalrymple's comprehensive, authoritative, and altogether magisterial account of the methods used to determine the age of the earth is, according to the reviewer for *The Quarterly Review of Biology*, “an enormously important book written by an expert for the general scientific public. It is must reading for all interested in the antiqui-

ty of nature." Dalrymple, a Supporter of NCSE, is Professor Emeritus in the College of Oceanic and Atmospheric Sciences at Oregon State University.

The Dating Game: One Man's Search for the Age of the Earth
by Cherry Lewis

"It is perhaps a little indelicate to ask of our mother earth her age, but science acknowledges no shame." So quipped Arthur Holmes, one of the major figures in the history of attempts to determine the age of the earth, and the subject of Cherry Lewis's lively biography, *The Dating Game*. The reviewer for *Earth Sciences History* writes, "it is always a pleasure — and alas, not a common pleasure — to read a really well-written geological biography. Cherry Lewis is to be congratulated not only in producing one such biography, but also in setting forth with commendable lucidity the evolving scientific concepts by which the Earth's dating was achieved."

Atlas of the Prehistoric World
by Douglas Palmer

As its title suggests, *Atlas of the Prehistoric World* contains a collection of dazzlingly detailed paleogeographic maps, tracking shifts in land masses and climates from the Vendian Period to the present. In addition, Douglas Palmer, who teaches Earth and Natural Sciences at Cambridge University, narrates the story of life's evolution over the course of the last four billion years and provides a sparkling history of and guide to earth science. Accompanied by over 250 full-color photographs and illustrations, *Atlas of the Prehistoric World* is a wonderful reference for the student, the teacher, and the enthusiast alike.

The Map that Changed the World
by Simon Winchester

In *The Map that Changed the World*, Simon Winchester tells the practically Dickensian story of William Smith and his struggle to create what was arguably the first true geological map. Winchester writes, "Geology, it seems almost redundant to say, underlies and underpins everything: the site of every city, every gold mine, every

field, every island is determined purely by geology — and humanity's condition is more directly influenced by geology than by any other aspect of the natural world. But until William Smith we could only surmise what that geology was, and what it would and could be elsewhere. We had no map."

GEOLOGY AND ITS HISTORY

Genesis and Geology

by Charles Coulston Gillispie

Subtitled "A study in the relations of scientific thought, natural theology, and social opinion in Great Britain, 1790-1850", *Genesis and Geology* "proposed to give an account of the immediate background of the pattern of scientific disagreement which culminated in disputes about Darwin's book and to attempt to analyze the causes of that disagreement." Originally published in 1951, *Genesis and Geology* was reprinted by Harvard University Press in 1996, with a new introduction by the historian of geology Nicolaas Rupke reevaluating the book in light of the subsequent 45 years of historical scholarship.

Time's Arrow/Time's Cycle

by Stephen Jay Gould

In *Time's Arrow/Time's Cycle*, Stephen Jay Gould reconsiders the discovery of deep time by focusing on "the three cardinal actors on the British geological stage — the primary villain and the two standard heroes", that is, Thomas Burnet, James Hutton, and Charles Lyell. Challenging textbook orthodoxies and Whiggish triumphalism in the history of geology, *Time's Arrow/Time's Cycle* was praised by the reviewer for the *Times Higher Education Supplement* as carrying "an enthusiasm, intelligence and sense of purpose that render it a worthy follower to Gould's earlier work." Gould was a supporter of NCSE until his death in 2002.

Great Geological Controversies

by Antony Hallam

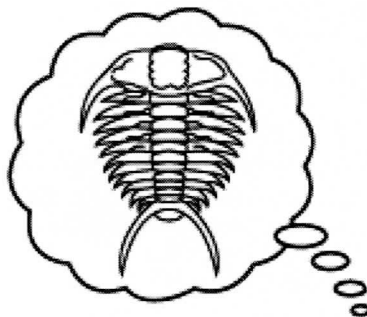
From the publisher: "a widely acclaimed account of the most celebrated controversies in the histo-

ry of geology — a book that covers many of the most important ideas that have emerged since the birth of the science. Among the great debates described here are those involving catastrophe theory, uniformitarianism, the discovery of the Ice Age, speculation concerning the age of the earth, and the advent of new ideas on plate tectonics and continental drift. In presenting these key topics, the author opens the fascinating history of geology to a wide audience. Frequently citing original sources, the author gives readers a sense of the colorful and at times immensely entertaining language of scientific discourse."

Plate Tectonics: An Insider's History of the Modern Theory of the Earth

edited by Naomi Oreskes

In *The Rejection of Continental Drift: Theory and Method in American Earth Science*, Naomi Oreskes traced the reception of continental drift in American geology from its initial rejection to its eventual acceptance. Now, in *Plate Tectonics*, she compiles the definitive history of the theory, told by the very scientists who developed and assembled evidence for it. Sections include The Historical Background, The Early Work: From Paleomagnetism to Sea Floor Spreading, Heat Flow and Seismology, The Plate Models, From the Oceans to the Continents, and Continents Really Do Move. Oreskes is Associate Professor of History at the University of California, San Diego.





NCSE on the Road

A CALENDAR OF SPECIAL EVENTS, PRESENTATIONS, AND LECTURES

DATE February 18, 2003
CITY Vermillion SD
PRESENTER Eugenie C Scott
TITLE Creationism and Evolution:
 Still Crazy After All These Years
EVENT University of South Dakota
 Sigma Xi Public Lecture
TIME 7:00 PM
LOCATION Farber Hall, Old Main, University of S Dakota
CONTACT Paula Mabee, pmabee@usd.edu

DATE March 5, 2003
CITY Conway AR
PRESENTER Eugenie C Scott
TITLE Why Do Scientists Reject "Intelligent Design"?
EVENT University of Central Arkansas Honors College
 "Challenge Week" Public Lecture
TIME 7:00 PM
LOCATION TBA
CONTACT James Murray, jmurray@mail.uca.edu

DATE March 26, 2003
CITY Philadelphia PA
PRESENTER Eugenie C Scott
TITLE The Slippery Slope to Creationism
EVENT Council of State Science Supervisors, National
 Science Teachers Association Annual Meeting
TIME 8:00 AM
LOCATION Pennsylvania Convention Center
CONTACT Jim Woodland, woodland@nde.state.ne.us

DATE April 9, 2003
CITY Spokane WA
PRESENTER Eugenie C Scott
TITLE The Old and New Anti-evolutionism:
 Creationism Evolves
EVENT Gonzaga University Biology Department
 Lecture Series
TIME 7:30 PM
LOCATION TBA
CONTACT Hugh Lefcort, lefcort@gonzaga.edu

DATE April 12, 2003
CITY Washington DC
PRESENTER Eugenie C Scott
TITLE Dogma 101: New Threats to Secular Humanism
EVENT Council for Secular Humanism
 International Conference
TIME TBA
LOCATION Capital Hilton, 16th and K
CONTACT Edward Buckner, buckner@centerforinquiry.net

DATE April 17, 2003
CITY Fullerton CA
PRESENTER Eugenie C Scott
TITLE Creation and Evolution
EVENT CSU University Honors and Scholars Series
TIME 7:00 PM
LOCATION Titan Student Union, ABC
CONTACT Jim Hofmann, jhofmann@fullerton.edu

[Check the NCSE web site for updates and details — <<http://www.ncseweb.org>>.]

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Variations in the Genetic Code: Evolutionary Explanations

Finn Pond and Jean Pond

The genetic code, deciphered in the 1960s, appeared at first to be the same for all organisms. The universality of the genetic code was hailed as strong evidence for a common ancestor, since it was difficult to imagine that a genetic code, once established, could be altered without killing the organism. But discovery of variant codes led biologists to reconsider their assumption that the genetic code was not subject to evolution. There is now evidence that the genetic code *can* be altered by natural processes, and that the variant codes existing in nature continue to provide evidence in support of biological evolution from a common ancestor.

But some critics of evolution take issue with any continued reference to a universal code, claiming that each of the different codes must be considered independent, rather than a variant of an original, "source" code. Indeed, some critics, specifically "intelligent design" proponents, have recently argued that the discovery of variations in the genetic codes of some organisms is evidence against the possibility that life on earth evolved from a single common ancestor (Discovery Institute 2001a, 2001b; Meyer 2001a, 2001b). They argue that if a universal code was once evidence for evolution from a common ancestor, then the absence of a universal code must be evidence against a common ancestor. This reasoning, however, is fallacious. They ignore evidence suggesting that the different codes represent minor deviations, in a small number of organisms, from this universal code. The argument that the absence of a universal code implies the absence of common ancestry is dependent upon the presupposition that the code is incapable of change, and this presupposition — as we shall explain — is no longer supported by the data.

What, then, is the evidence and reasoning behind the claim of biologists that variations in the genetic code are compatible with, and indeed support, the claim of common ancestry?

THE BASIS OF GENETIC CODING AND THE TRANSLATION OF THE CODE

By about 1966, working mainly with the bacterium *Escherichia coli*, scientists had established what came to be regarded as the universal genetic code (Crick

1966; Osawa 1995). The "genetic code" is the system by which information encoded in RNA is translated into an amino acid sequence. DNA and RNA are made up of 4 nucleotides (in DNA, adenine, guanine, cytosine, and thymine, abbreviated A, G, C, and T; in RNA, uracil, abbreviated U, stands in for T). The code is based on groupings of three nucleotides called "codons". There are 64 possible ways to arrange the four nucleotides into groups of 3. Sixty-one of these codons specify how specific amino acids are incorporated into a protein molecule. The 3 remaining codons signal termination of protein synthesis.

The genetic code is said to be degenerate because there are only 20 amino acids coded for by the 61 codons. Consequently, there are duplications in the code. That is, more than one codon may code for the same amino acid (Table 1). When several codons specify the same amino acid, the difference between them is generally in the third base (Table 2). For example, isoleucine is coded for by AUU, AUC, and AUA.

Transfer RNA (tRNA) is the adaptor molecule that links a specific codon with a specific amino acid. Each tRNA molecule binds a specific amino acid. Transfer RNA molecules then pair with the codons of an RNA message by means of a three-base sequence on the tRNA called the anticodon. The pairing is based on hydrogen bonding between anticodon and codon bases. Thus, the sequence of codons in an RNA message specifies the sequence of amino acids that go into the formation of a protein.

A specific tRNA molecule is not required for each of the 61 codons. The biochemical and molecular characteristics of tRNA allow a single tRNA to recognize more than one codon. This is explained by the potential "wobble" in the first base of the anticodon (pairing with the third base of the codon). The spatial arrangement of codon-anticodon interaction in this position allows deviation from the standard Watson-Crick pairing (A pairing with U, and G pairing with C). Thus, a single tRNA can recognize more than one codon (Table 3). The standard nuclear code requires a minimum of 32 tRNAs to translate all 61 codons. The mitochondrial code (used by mitochondria — organelles in eukaryotic cells that carry genetic material different from that in the cell nucleus), uses a simplified codon-anticodon pairing scheme and requires only 22 tRNAs.

NATURAL VARIATIONS IN THE GENETIC CODE

Assuming a common, universal ancestor for all organisms, geneticists expected that all organisms would share the same genetic code (Crick 1968; Osawa 1992). Indeed, as the molecular genetics of organisms from

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bacteria to humans began to be studied in detail, it first appeared that the genetic code was in fact universal.

Then, in 1979, it was discovered that the mammalian mitochondrial code differed from the universal code. (Note that some texts still use the term "universal code" for historical reasons and also because all variant codes are thought to be modifications of this code. The terms "standard code" and "canonical code" are also used [Barrell and others 1979].) The differences were minor: AUA coded for methionine instead of isoleucine, and UGA coded for tryptophan instead of signaling termination of protein synthesis. Nevertheless, this discovery raised questions about the development, evolution, and universality of the genetic code.

To account for variations in the mitochondrial codes, it was proposed that the small genome (only 10–20 proteins) encoded by mitochondrial DNA might allow code changes that would be intolerable on a cellular scale (Jukes 1981). It is certainly possible to alter an amino acid at a given position within a protein without seriously hindering protein function; consider, for example, the many isozymes and other documented protein variations. Nevertheless, the reassignment of a codon from one amino acid to another, even if the change is conservative (for example, one acidic amino acid for another), will result simultaneously in many amino acid changes, in all probability producing a non-functional set of proteins. Consequently, people questioned whether even the mitochondrial genome could tolerate such codon reassignments.

As mitochondrial variations were cataloged, however, it was noted that most of them involved termination codons. Perhaps the effect of extending the amino acid sequence of proteins is less detrimental than resequencing. This explanation also seemed unreasonable to many. The debate, however, became pointless, when, in 1985, variations that involved different codon assignments were discovered in the nuclear codes of a bacterium and several ciliated protists (Caron and Meyer 1985; Helftenbein 1985; Horowitz and Gorovsky 1985; Jukes 1985; Kuchino and others 1985; Preer and others 1985). Clearly it was improbable for widespread codon reassignments to occur for proteins throughout a cell without undermining cellular function. If the genetic code is to be altered, there must be a way to introduce changes without jeopardizing cell survival.

Since that time, many more variations from the standard code have been documented (Elzanowski and Ostell 2000; Knight and others 2001) (Table 4).

POSSIBLE EXPLANATIONS FOR VARIATIONS IN THE GENETIC CODE

Explanations for the existence of variant codes must either accept multiple origins of life or argue that the genetic code is subject to evolutionary change. The basic idea of the "independent-origins" hypothesis is that each genetic code has an independent origin and therefore organisms possessing different codes are not evolutionarily related and descent from a common ancestor has not occurred for all life forms. The independent-origins hypothesis in effect assumes that plausible mechanisms for altering the genetic code do not exist. The alternative hypothesis is that variant codes evolved from a historically universal code. The basic idea here is that, following establishment of a common

SECOND POSITION						
		U	C	A	G	
FIRST POSITION	U	phenylalanine	serine	tyrosine	cysteine	U C
		leucine		stop stop	stop tryptophan	A G
	C		leucine	proline	histidine	arginine
		glutamine				
A	isoleucine	threonine	asparagine	serine	U C	
	methionine		lysine	arginine	A G U	
G	valine	alanine	aspartate	glycine	C A G	
			glutamate			

A common representation of the standard genetic code. The 4 possible nucleotides in the first position of a codon are listed on the left-hand side of the table; possible nucleotides in the second and third positions are listed along the top and right-hand side, respectively. The amino acids coded for by the different possible codons (formed from the various combinations of nucleotides) are indicated in the body of the table.

A common representation of the standard genetic code. The 4 possible nucleotides in the first position of a codon are listed on the left-hand side of the table; possible nucleotides in the second and third positions are listed along the top and right-hand side, respectively. The amino acids coded for by the different possible codons (formed from the various combinations of nucleotides) are indicated in the body of the table.

TABLE 2. CODONS FOR SELECTED AMINO ACIDS ACCORDING TO THE STANDARD GENETIC CODE

AMINO ACIDS CODED BY 6 DIFFERENT CODONS

Amino Acid:	Arginine	Leucine	Serine
Codons	CGU CGC CGA CGG AGA AGG	CUA CUG CUU CUC UUA UUG	UCU UCC UCA UCG AGU AGC

AMINO ACIDS CODED BY 4 DIFFERENT CODONS

Amino Acid:	Alanine	Glycine	Proline	Threonine	Valine
Codons	GCU GCC GCA GCG	GGU GGC GGA GGG	CCU CCC CCA CCG	ACU ACC ACA ACG	GUU GUC GUA GUG

AMINO ACIDS CODED BY 2 DIFFERENT CODONS

Amino Acid	Asparagine	Aspartate	Cysteine	Glutamine	Glutamate
Codons	AAU AAC	GAU GAC	UGU UGC	CAA CAG	GAA GAG
Amino Acid	Histidine	Lysine	Phenylalanine	Tyrosine	
Codons	CAU CAC	AAA AAG	UUU UUC	UAU UAC	

Of the 20 amino acids coded by the nucleotide bases in DNA and RNA, 15 of them are coded by at least 2 different sequences. In all but 3 of the amino acids, the alternative codons differ only in the base that occupies the third position. In the amino acids coded by 6 different sequences, 2 of the alternatives show variation in both the first and third positions in the sequence. (Note that tryptophan and methionine — not shown here — have unique codons.)

ancestral code, variations in the code appeared in different lineages. The evolution of the genetic code hypothesis in effect assumes, contrary to expectations of biologists in the 1960s and early 1970s, that the genetic code is subject to evolutionary processes. This requires a mechanism by which variations in the genetic code can be introduced without extensive disruption of protein structures and cellular functions. These two hypotheses seem to cover the space of logical possibilities.

EVALUATING THE PROPOSALS FOR INDEPENDENT ORIGINS OF THE GENETIC CODE

The basic argument for the independent-origins hypothesis is that genetic codes are functionally invariant and cannot be altered without killing the organism. Even postulating that very few proteins might have

TABLE 3. "WOBBLE" BASE-PAIRING

First Nucleotide of tRNA Anticodon	Possible Base-pair Binding with Third Base of Codon
A	U
C	G
G	C or U
U	A or G
I*	A, C, or U

* Inosine is a modified base derived from adenosine and is found in tRNA.

TABLE 4. DEVIATIONS FROM THE STANDARD GENETIC CODE

Taxa showing Mitochondrial Variations	Codon Assignment*	Standard Codon Assignment
vertebrates	AGR = termination AUA = methionine UGA = tryptophan	arginine isoleucine termination
yeast	AUA = methionine CUN = threonine	isoleucine leucine
molds, protists, coelenterates	UGA = tryptophan	termination
nematodes, mollusks, arthropods	AGR = serine AUA = methionine UGA = tryptophan	arginine isoleucine termination
echinoderms	AAA = asparagine AGR = serine UGA = tryptophan	lysine arginine termination
round worms	AGR = glycine AUA = methionine UGA = tryptophan	arginine isoleucine termination
flatworms	AAA = asparagine AGR = serine UAA = tyrosine UGA = tryptophan	lysine arginine termination termination
Taxa showing Nuclear Variations	Codon Assignment*	Standard Codon Assignment
mycoplasma, spiroplasma	UGA = tryptophan	termination
ciliates, green algae	UAR = glutamine	termination
yeast	CUG = serine	leucine

Note: Deviations are not necessarily found throughout the taxa indicated.

* R = any purine (A or G), N = any nucleotide (A, G, C, or U)

been involved (that is, in a very primitive "cell") and that the changes were conservative (replacing one type of amino acid with a similar one), it seems highly unlikely that a wholesale change in the cell's proteins could be benign.

The weakness of this argument is that it assumes any change in the genetic code must occur as a spontaneous replacement of one amino acid for another throughout all proteins. In other words, this argument is based on an extreme scenario. Consideration of codon usage and codon selection, however, has suggested that there are other, less extreme scenarios (as we discuss below). Consequently, to maintain this position, one must show that there is no possible mechanism by which genetic codes can evolve.

There are other problems with the independent-origins hypothesis. If there were indeed multiple origins of life, then an explanation is needed to account for the fact that, regardless of the genetic code used, the basic molecular and biochemical machinery of cells is the same. The independent-origins hypothesis must also account for the high degree of similarity among protein and DNA sequences found in different lineages of organisms. We find, for example, that a common set of L-amino acids (the "left-handed" form of the compounds) is used by all known organisms. If different genetic codes reflect independent origins, should we not expect to see the use of different sets of amino acids in organisms from different lineages, including

perhaps the use of D-amino acids (the "right-handed" forms)? In addition, the differences among the variant codes are minor: that is, they appear to be variants of a standard code rather than unique codes. This too must be explained by the independent-origins hypothesis.

How can the similarity of proteins, genetic material, and genetic codes in different organisms be explained by someone who accepts the independent-origins hypothesis? One possibility is to postulate that the similarities exist because there are only a limited number of ways to generate functional cells. In other words, the similarities are due not to common descent but to the fact that the laws of chemistry and physics entail that no dissimilar structures would be viable. Call this the laws-of-nature proposal. Another possibility — the one espoused by the proponents of "intelligent design" — is to say that these similarities exist because a "Designer" chose to use a related design for various organisms. Call this the design proposal.

Let us address the laws-of-nature proposal first. It should be acknowledged that there is reason to believe that the genetic code is not entirely arbitrary. The pattern of codon assignment has been analyzed and shown to minimize the effects of mutations on protein structure (Freeland and Hurst 1998; Freeland and others 2000). It has been strongly argued that fundamental principles of thermodynamics and biochemistry are likely to have constrained development of the genetic code and may continue to restrict the extent of variation possible (Knight and others 1999). It has also been shown that selection pressure, at least in some situations, may favor one code variant over another (Santos and others 1999).

But biochemical and thermodynamic constraints must not be confused for determination. Although there certainly must have been biochemical constraints involved in the development of the metabolic and genetic machinery of a cell and in the establishment of a genetic code, there is no compelling reason to suspect that such constraints would have required life independently to evolve such similar — indeed in many cases identical — proteins, genetic sequences, and genetic codes (Knight and others 1999). Independent origins should result in clear molecular and biochemical differences among the groups of organisms that possess different codes. There is no evidence for the claim that the laws of nature would require different groups of organisms, evolving independently, to share the widespread genetic and protein similarities that are found, for example, among those groups of bacteria or ciliates that possess different codes.

Another difficulty with the laws-of-nature proposal is that any phylogeny based only on genetic code variants would align poorly with phylogenies based on other lines of evidence. If no organism with a given genetic code were related to any organism with a different genetic code, then it would be difficult to explain the similarities among their proteins or their genetic sequences without invoking a further, and suspiciously ad hoc, set of laws of nature. A mutational explanation for the evolution of genetic code variants, on the other hand, aligns well with a phylogeny supported by comparisons of protein and genetic sequences (Knight and others 2001).



What about the design proposal, a variant of which has recently surfaced (Discovery Institute 2001a, 2001b; Meyer 2001a, 2001b)? The Discovery Institute's Center for Science and Culture and its Senior Fellow Stephen C Meyer attempt to discredit an evolutionary explanation for variant genetic codes by suggesting that the variations themselves count against the possibility of descent of life from a common ancestor. They assume the functional inviolability of the genetic code, an assumption that, as we explain below, is untenable in the light of current scientific knowledge. But what is the alternative that they propose?

The proponents of "intelligent design" claim that the nature of information and the complexity of the cellular machinery required to store, retrieve, and process genetic information precludes the possibility that genetic systems could develop by any natural process (for example, Meyer 2000). They claim, then, that the genetic code can only be attributed to an "intelligent designer", which implemented the same genetic code in genealogically unrelated organisms, presumably for reasons of its own. (It would also be possible for a proponent of "intelligent design" to argue specifically from the existence of variant genetic codes, by citing the selective advantage of some code variants or the error-minimizing pattern of coding assignments as evidence of "intelligent design". But these are explained by evolution as well, and it is hard to see that "intelligent design" is in any respect a better explanation. Evolution also explains neutral mutations in the code and non-optimal code variants, which could be explained by "intelligent design" only with the aid of ad hoc contortions.)

Evolutionists respond by pointing out the vast body of molecular, biochemical, physiological, anatomical, and behavioral evidence showing clear genealogical relationships among organisms. How do the proponents of "intelligent design" handle the body of observations about living systems? Their arguments are not comprehensive enough for us to make sense of them. If common features simply reflect design constraints, then what are those constraints? If common features reflect the signature of a "designer", then how are shared mutations among organisms, for example, to be accounted for? And what explanation is offered for the variant genetic codes? Are they too designed, or are they an unplanned byproduct? The proponents of "intelligent design" are silent about these fascinating questions.

THE EVOLUTION OF THE GENETIC CODE

The widely held position of biologists is that all life on earth is derived from a common ancestry. Biologists understand common ancestry to mean a founding population that shared a biologic and genetic composition yet within which we would expect to find variation among the individuals. A single genetic code is believed to have characterized early life forms, and deviations from this standard code have occurred by natural evolutionary mechanisms. Thus, today we find a number of variant genetic codes.

If this hypothesis is correct, we should expect to find evidence of a close similarity between the derivative codes and the parent code, phylogenetic patterns in the variant codes, and evidence that there are mechanisms

by which the genetic code could be altered without destruction of the cell.

Is there a clear similarity between variant codes and the standard code? Simple inspection of the non-standard codes reveals that in most cases only a single codon is altered, usually a stop or start codon (which specifies the initiation or termination of protein synthesis). If fundamentally different codes were found, this would indeed be strong evidence for multiple origins of life. There are other changes in the standard code besides those involving start and stop codons, and in some variant codes more than one change has occurred, but in no case are the changes so extensive as to vitiate the claim of clear similarity. The variations in the genetic code are minor.

The linkage of variant codes to the standard code makes phylogenetic sense. A recent analysis of code variations demonstrates links to the standard code and a pattern of relationships consistent with phylogenies established by other lines of evidence (Knight and others 2001). Recent claims by proponents of "intelligent design" that the above analysis does not show evolutionary relationships have been addressed by Kenneth Miller, who demonstrates that the proponents of "intelligent design" have badly misunderstood and misrepresented the significance of the data presented in this paper (Discovery Institute 2001a, 2001b; Miller 2001a, 2001b).

But the real issue is whether the genetic code is subject to evolutionary change. Are there possible mechanisms for such change or not? Mutations in the tRNAs are the most likely means for altering the genetic code since they act as adaptor molecules, translating a DNA nucleotide sequence into an amino acid sequence. One possibility by which the genetic code can be changed is that the anticodon of a tRNA mutates, thereby linking a particular amino acid to a different codon. Suppose, for example, that Met-tRNA^{met} (a tRNA molecule carrying the amino acid methionine and recognizing the AUG codon) undergoes a mutation in its anticodon from 3'-UAC to 3'-UAU. That anticodon would still recognize the AUG codon (due to base wobble) but would now also recognize the AUA codon, which normally codes for the amino acid isoleucine. Thus the mutated tRNA^{met} can replace an isoleucine with a methionine in a protein structure. If the AUA codon (for isoleucine) is also correctly recognized according to the standard code by its "standard tRNA", then a period of ambiguity would result. One of two amino acids would be incorporated into a protein: the standard amino acid by the standard tRNA and a different amino acid by the mutated tRNA (that is, either methionine or isoleucine could be incorporated into the protein when an AUA codon is encountered, depending upon which tRNA happens to get to the codon first). The ambiguity would persist until one assignment is eliminated. If that codon is not currently assigned an amino acid, however, then the genetic code is effectively changed in a single mutational event (see the section below on codon capture).

There are other ways to change coding assignments. Chemical modification of the standard nucleotides (A, G, C, and U) is common in tRNAs, and it has been shown that different modifications affect the codon and anticodon binding (Knight and others 2001;



ADDITIONAL RESOURCES ON THE GENETIC CODE

Here are two additional resources for those interested in an introduction to the origin and history of the genetic code.

Maynard Smith J, Szathmari E. *The Major Transitions in Evolution*. San Francisco: WH Freeman, 1995.

Wong, JTF (1988) Evolution of the genetic code. *Microbiological Science* 5: 174-81.

[Thanks to Larry Moran for these suggestions.]

Matsuyama and others 1998). It has also been demonstrated that mutations in tRNAs in locations other than the anticodon can affect codon recognition by altering the 3-dimensional shape of the molecule (Nelson and Cox 2000). In some cases, the tRNAs are edited after they are constructed (a C in the anticodon, for example, might be replaced with a U; Alfonso and others 1999). All of these changes in tRNAs can affect their codon recognition, potentially leading to an altered genetic code. Finally, it is possible also that a tRNA may begin binding a different amino acid than is specified in the standard code (due to a change in the activity of an aminoacyl-tRNA-synthetase — one of the enzymes that link tRNA and amino acids).

It should also be pointed out that the genetic code is not always read simply as a sequence of triplet nucleotides. In some bacteria, an unusual amino acid, selenocysteine, is incorporated into a developing protein even though there is no "selenocysteine codon". A modified serine tRNA incorporates selenocysteine into protein at certain UGA codons (normally a termination codon). This only happens at UGA codons situated within a particular context (Stadtman 1996). Thus the genetic code can be read differently in different circumstances.

It was recently discovered that the archaebacterium *Methanosarcina barkeri* uses a UAG "stop codon" in methyltransferase genes to code for pyrrolysine (a non-standard amino acid; Srinivasan 2002). It appears that a unique lysyl-tRNA synthetase places a lysine residue onto a UAG-decoding tRNA. At what point the lysine is modified to pyrrolysine is unclear, but the examples of selenocysteine and pyrrolysine demonstrate that genetic codes are subject to modification.

Another important feature of the genetic code is differential codon usage: when more than one codon specifies a particular amino acid, not all of these cognate codons are used in equal frequency. Codon usage varies as a reflection of different base content (Osawa 1995; Osawa and others 1992). An organism that has a higher G + C content is more likely, when a choice of codons is available, to utilize codons that make use of Gs and Cs. Since the G + C content of DNA varies considerably, codon usage will also vary among organisms. The consequence of variable codon usage is that in some organisms, certain codons are not found at all. For example, in the bacterium *Mycoplasma capricolum*, the codon CGG is never found. Furthermore, the tRNA needed to translate the CGG codon is also absent from this bacterium. In another example, the yeast *Torulopsis glabrata* only uses AGA and AGG to code for arginine. The four other codons that also specify arginine and the tRNA required to translate these codons are absent. That an organism may not use all codons

suggests some possibilities for codon reassignment. Also, in many cases there is more than one variant of tRNA that reads a particular codon, and there are often multiple genes for a given tRNA. This also creates potential for reassignments.

Mutational events affecting the anticodons or other critical nucleotides in tRNA molecules have been observed in the laboratory. One type of mutation, known as a suppressor mutation, can be easily demonstrated (Nelson and Cox 2000). A nonsense mutation occurs when a codon specifying an amino acid mutates to a termination codon. In such a case, protein synthesis will be prematurely aborted, usually resulting in a defective protein. Normal function can be restored if the gene for a tRNA mutates to produce a tRNA that can recognize the termination codon. Protein synthesis can continue because the code is altered to allow a stop codon to be read as an amino acid-specifying codon. Suppressor mutations most often involve changes in the anticodon of a tRNA. Since there are usually multiple copies of tRNA genes, one gene can mutate to give rise to the suppressor tRNA without disrupting translation of other codons. The releasing factor that recognizes the termination codon is still functional, so there is ambiguity in the reading of the code; the point, however, is that a change in the reading of the genetic code has occurred.

At least three mechanisms have been proposed that — using changes such as those described above — can account for the establishment of a variant code. The three are not mutually exclusive and it is possible that different changes in coding assignments are attributable to different mechanisms. Knight and his colleagues have considered the three mechanisms and offer testable predictions derived from each (Knight and others 2001).

CODON CAPTURE

The "codon capture" hypothesis says that after a codon is lost from use, it may be reassigned through mutational events affecting tRNA-codon recognition (Osawa 1995; Osawa and others 1992). One plausible scenario is described as follows. AUA in the standard code specifies the amino acid isoleucine, but in mitochondria it often codes for methionine. The tRNA^{Ile} that normally recognizes AUA has a 3'-UAC anticodon (the C has been modified to bind to A but not G and therefore does not recognize AUG codons). If this tRNA^{Ile} is lost (and it is known to be absent in many mitochondria) then the AUA codon becomes unassigned. A modification of the tRNA^{Met} anticodon either by an anticodon mutation or nucleotide modification can change its specificity from the AUG codon to include both the AUG and AUA codons. Modified tRNAs for methionine that do this are found in echinoderm mitochondria, for example. This change in the code could occur without disrupting cell function.

Evidence supporting the codon capture model comes from studies of the mitochondrial genome of *Balanoglossus carnosus*, a hemichordate. Castresana and his colleagues show that in *B. carnosus* mitochondria, the codon AAA is not used, nor is there a tRNA to recognize this codon. In the standard code, AAA codes for lysine, but in echinoderm mitochondria, AAA codes for asparagine. These observations fit nicely with the



codon capture hypothesis; the *B. carnosus* code is intermediate between the ancestral and the derived code, having lost the AAA codon, which becomes reassigned (Castresana and others 1998).

AMBIGUOUS INTERMEDIATE

The "ambiguous intermediate" hypothesis proposes that an ambiguous codon assignment can be resolved by selective pressure (Santos and others 1999; Schultz and Yarus 1996). A new assignment can result if it is advantageous under certain circumstances. For example, in *Candida* species, the CUG codon can be translated as either serine or leucine because the tRNA can be charged with different amino acids. It has been shown that when produced in *Saccharomyces cerevisiae*, this *Candida* tRNA alters protein folding so that the yeast becomes more resistant to various environmental insults. Thus, it seems plausible that an altered code could be subject to natural selection.

GENOME STREAMLINING

The "genome streamlining" hypothesis suggests that there might be selection in some systems (for example, mitochondria) to reduce the number of tRNAs and modifying enzymes required to synthesize proteins (Anderson and Kurland 1995). For example, AUA and AUG each require separate tRNAs in the standard code and according to rules of wobble base pairing, but a common variation in mitochondria is to use a single tRNA^{Met} to recognize both codons.

CONCLUSIONS: CAN THE GENETIC CODE EVOLVE?

Proponents of "intelligent design" are quick to quote statements from the earlier literature (mid-1960s to mid-1980s) to the effect that the hypothesis of a common ancestor predicts a universal code, but they fail to point out that such comments were based on the general assumption of that time that no mechanisms existed for changes in the code. When evolutionists discovered that variations in the code do exist, and after considering the nature and extent of these variations, they came to the conclusion that the code does in fact evolve. The development of new and more complete understandings in science is standard operating procedure.

Proponents of "intelligent design" acknowledge that mechanisms have been proposed to account for code evolution, but they offer no analysis to suggest why these mechanisms might be inadequate or how "intelligent design" offers a better explanation of the observed facts. And despite all the rhetoric, the real question has not changed. What actually happens in nature? Can genetic codes change or not?

Are there reasons to conclude that the different codes are variants of the "universal" or standard code? Yes. Are there plausible mechanisms to account for these variations? Yes. Are these mechanisms compatible with our understanding of biochemical, molecular, and evolutionary processes? Yes.

There is no inconsistency or incompatibility between the existence of variant codes and the theory of universal common ancestry. Where the problem lies is with our earlier understanding of molecular mechanisms. We are more aware now of molecular variations

in nature, but clearly there is more to learn. We have been surprised on numerous occasions in the past, and nature will no doubt continue to surprise us. These unexpected findings have strengthened and enriched our understanding of evolutionary processes and have not given cause for a rethinking of the idea of a common ancestor.

The proponents of "intelligent design" offer no evidence to warrant the abandonment of a well-supported theory. Simply claiming that the evolution of the genetic code could not have occurred because they find it unlikely — and this is what Meyer's rhetoric really boils down to — remains an unconvincing argument for most scientists. The "argument from personal incredulity" has no place in science or any scholarly inquiry. Hans Spemann, the great experimental embryologist, once remarked: "We still stand in the presence of riddles, but not without hope of solving them. And riddles with the hope of solution — what more can a scientist desire?" (quoted in Gilbert 2000).

Proponents of "intelligent design" question the open-mindedness of biologists, claiming that some alleged commitment to a materialist philosophy has biased our thinking. Biologists do not object to honest critiques of their work: such critiques are routinely made in the scientific literature. What is objectionable, however, is when data and hypotheses are misrepresented, selectively presented, or simply ignored.

REFERENCES

- Alfonso JD, Blanc V, Estevez AM, Rubio MA, Simpson LC. C to U editing of the anticodon of imported mitochondrial tRNA (Trp) allows decoding of the UGA stop codon in *Leishmania tarentolae*. *European Molecular Biology Organization Journal* 1999; 18: 7056–62.
- Andersson SG, Kurland CG. Genomic evolution drives the evolution of the translation system. *Biochemistry and Cell Biology* 1995; 73: 775–87.
- Barrell BG, Bankier AT, Drouin J. A different genetic code in human mitochondria. *Nature* 1979; 282: 189–94.
- Caron E, Meyer E. Does *Paramecium primaurelia* use a different genetic code in its macronucleus? *Nature* 1985; 314: 185–8.
- Castresana J, Feldmaier-Fuchs G, Paabo S. Codon reassignment and amino acid composition in hemichordate mitochondria. *Proceeding of the National Academy of Sciences USA* 1998; 95: 3703–7.
- Crick FHC. The genetic code: III. *Scientific American* 1966; 215: 55–62.
- Crick FHC. The origin of the genetic code. *Journal of Molecular Biology* 1968; 38: 367–79.
- The Discovery Institute. "Evolution" series charged with "false claim" on "universal genetic code". 2001a; available from <http://www.reviewevolution.com/press/pressRelease_FalseClaim.php>. Last accessed December 27, 2001.
- The Discovery Institute. Reply to Kenneth Miller on the genetic code. 2001b; available from <http://reviewevolution.com/press/pressRelease_ReplyMiller.php>. Last accessed December 27, 2001.
- Elzanowski A, Ostell J. The genetic codes. National Center for Biotechnology Information. 2000; available from <<http://www.ncbi.nih.gov/htbin-post/Taxonomy/>>. Last accessed December 27, 2001.
- Freeland SJ, Hurst LD. The genetic code is one in a million. *Journal of Molecular Evolution* 1998; 47: 238–48.
- Freeland SJ, Knight RD, Landweber LE, Hurst LD. Early fixation of an optimal genetic code. *Molecular Biology and Evolution* 2000; 17: 511–8.
- Gilbert SE. *Developmental Biology*, 6th ed. Sunderland (MA): Sinauer Associates, 2000.
- Helftenbein E. Nucleotide sequence of a macronuclear DNA molecule coding for alpha-tubulin from the ciliate *Stylonychia lemnae*. Special codon usage: TAA is not a translation termination codon. *Nucleic Acid Research* 1985; 13: 415–33.
- Horowitz S, Gorovsky MA. An unusual genetic code in nuclear genes from *Tetrahymena*. *Proceedings of the National Academy of Science (USA)* 1985; 82: 2452–5.
- Jukes TH. Amino acid codes in mitochondria as possible clues to primitive codes. *Journal of Molecular Evolution* 1981; 18: 15–7.
- Jukes TH. A change in the genetic code in *Mycoplasma capricolum*. *Journal of Molecular Evolution* 1985; 22: 361–2.





Trading on Genomes: Recent Creationists Use Genomic Data from Mycoplasmas

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INTRODUCTION

The advent of high-throughput automated sequencing has given the discipline of genetics the complete genomic sequence of several model organisms, including humans (Lander and others 2001; Venter and others 2001), rice (Goff and others 2002; Yu and others 2002), weeds (Lin and others 1999; Mayer and others 1999; Adam 2000; Salanoubat and others 2000; Tabata and others 2000; Theologis and others 2000), worms (Bargmann 1998; Blaxter 1998; Clarke and Berg 1998; Ruvkun and Hobert 1998), fruit flies (Adams and others 2000; Myers and others 2000), and yeasts (Goffeau and others 1996; Wood and others 2002). This explosion of sequence data has given birth to the new subdiscipline called genomics, which examines organisms from a whole-genome perspective. If our genes are trees and our genomes a forest, then genomics allows geneticists to examine the whole forest at one time instead of spending our time focusing on one or a few trees (Gibson and Muse 2002).

By far the group that hosts the widest range and

largest number of organisms whose genomes have been completely sequenced are the prokaryotes, that group we colloquially know as the bacteria. Genomes from both free-living and pathogenic bacteria have been completely sequenced, as have genomes from many eubacteria and several members of the Archaea (Fraser 2002). Because of their small, compact genomes and the relative ease of growing large numbers of them, bacterial organisms make prime candidates for genomic sequencing.

Genomics has revolutionized the way questions are addressed and has provided valuable insight into how genomes evolve (Arber 2002; Doolittle 2002; Knight 2002). Nevertheless, creationists, such as Bryan College's Todd C Wood, are using genomic data to support their contention that living things were independently created only a few thousand years ago. These "recent creationists" claim that completed genomic sequence data from bacteria called mycoplasmas chal-

Knight RD, Freeland SJ, Landweber LF. Selection history and chemistry: The three faces of the genetic code. *Trends in Biochemical Sciences* 1999; 24: 241-7.

Knight RD, Freeland SJ, Landweber LF. Rewiring the keyboard: Evolvability of the genetic code. *Nature Reviews — Genetics* 2001; 2: 49-58.

Kuchino Y, Hanyu N, Tashiro F, Nishimura S. *Tetrahymena thermophila* glutamine tRNA and its gene that corresponds to UAA termination codon. *Proceedings of the National Academy of Science (USA)* 1985; 82: 4758-62.

Matsuyama S, Ueda T, Crain PF, McCloskey JA, Watanabe K. A novel wobble rule found in starfish mitochondria. Presence of 7-methylguanosine at the anticodon wobble position expands decoding capability of tRNA. *Journal of Biological Chemistry* 1998; 273: 3363-8.

Meyer S. DNA and other designs. *First Things* 2000 Apr; 102: 30-8. Available from <<http://www.firstthings.com/ftissues/ft0004/articles/meyer.html>>. Last accessed July 8, 2002.

Meyer S. Darwin's public defenders. 2001a; available from <http://www.worldnetdaily.com/news/article.asp?ARTICLE_ID=24710>. Last accessed December 27, 2001.

Meyer S. Meyer exchange at Whitworth College. 2001b; available from <<http://www.discovery.org/viewDB/index.php3?program=CRSC%20Responses&command=view&id=1090>>. Last accessed December 27, 2001.

Miller K. A "dying theory" fails again. 2001a; Available from <http://www.ncseweb.org/resources/articles/3071_km_3.pdf>. Last accessed December 27, 2001.

Miller K. DI fails again to "crack" the code. 2001b; available from <http://www.ncseweb.org/resources/articles/6249_pr89_10182001_di_fails-aga-10_18_2001.asp>. Last accessed December 27, 2001.

Nelson DL, Cox MM. *Lehninger Principles of Biochemistry*; 3d ed. New York: Worth Publishers, 2000.

Osawa S. *The Evolution of the Genetic Code*. Oxford: Oxford University Press, 1995.

Osawa S, Jukes TH, Watanabe K, Muto A. Recent evidence for evolution of the genetic code. *Microbiological Reviews* 1992; 56: 229-64.

Preer JR Jr, Preer LB, Rudman BM, Barnett AJ. Deviation from the universal code shown by the gene for surface protein 51A in *Paramecium*. *Nature* 1985; 314: 188-90.

Santos MA, Cheesman C, Costa V, Moradas-Ferreira P, Tuite MF. Selective advantages created by codon ambiguity allowed for the evolution of an alternative genetic code in *Candida* spp. *Molecular Microbiology* 1999; 31: 937-47.

Schultz DW, Yarus M. On malleability in the genetic code. *Journal of Molecular Evolution* 1996; 42: 597-601.

Srinivasan G, James CM, Krzycki JA. Pyrrolysine encoded by UAG in Archaea: Charging of a UAG-decoding specialized tRNA. *Science* 2002; 296: 1459-62.

Stadtman TC. Selenocysteine. *Annual Review of Biochemistry* 1996; 65: 83-100.

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lenge evolutionary theory (Wood 2001); this article is an evaluation of Wood's efforts. As we shall see, in order to fit the genomic data into his recent creationist paradigm, Wood has to ignore previous work on mycoplasmal phylogeny and misrepresent contemporary evolutionary thinking with respect to parasitism.

MYCOPLASMAS – MIGHTY BUT MINISCULE

Mycoplasmas are very small, prokaryotic organisms that lack a cell wall. Their small size and flexibility allows them to pass through bacteriological filters — a feature that makes them frequent nuisances in cell cultures. Mycoplasmas also have very small genomes that are one-fourth or less the size of most bacterial genomes — a feature that make them particularly good candidates for genomic studies (Woese and others 1985). Mycoplasmal DNA has higher proportions of the nucleotides adenine and thymine (they are “A-T rich”), and mycoplasmas show unusual nutritional requirements (Weisburg and others 1989). Mycoplasma and mycoplasma-like organisms (MLOs) collectively compose a class of microorganisms called *Mollicutes*. *Mollicutes* contains a variety of organisms that show strong symbiotic associations with other living organisms. Some are associated with insects and plants (*Entomoplasmas*, *Mesoplasma*, and *Spiroplasma*), others are oxygen-sensitive and found in the rumens of bovine and ovine mammals (*Anaeroplasm* and *Asteroleplasma*), and some associate with plants, insects, and warm-blooded animals, but do not require sterols for growth (*Acholeplasma*; Tully and others 1993). The largest subgroup within the mollicutes is the mycoplasmas, which consists of organisms from the genera *Mycoplasma* and *Ureaplasma* that must associate with humans and other warm-blooded animals to survive; in some cases, they cause human and animal diseases (Razin and others 1998). Not surprisingly, completed genomes of several mycoplasmas are available (Fraser and others 1995; Himmelreich and others 1996; Glass and others 2000; Chambaud and others 2001). The genome of *Mycoplasma genitalium* (see cover) is the smallest known at 568 070 base pairs (Fraser and others 1995). Many plant MLOs have not been cultured to date, which has delayed their characterization (Lim and Sears 1989).

MYCOPLASMAS ACCORDING TO WOOD

Wood begins his article by asserting that all disease, pain, and suffering are the result of the sin of Adam and Eve (Wood 2001: i). He states, “Creationists generally explain the Curse-related imperfections as degenerations of originally beneficial structures.” This is a common recent creationist belief, but this statement essentially endorses the evolutionary concept of exaptation, in which characters that serve particular purposes initially are later co-opted for new functions (Futuyma 1998). In the case of pathogenic bacteria, these microorganisms possess virulence factors, which help them to cause disease by adhering to or damaging host tissues or evading the host immune system (Hacker and others 1997; Hacker and Kaper 2000; Henderson and others 1996; Kathariou 2002; Law and Chart 1998; Potempa and others 2000). However, according to

Wood, these virulence factors arose from features that were not originally used for that purpose. Consequently, Wood would argue, for example, that exotoxin A from the soil bacterium and opportunistic pathogen *Pseudomonas aeruginosa*, which inactivates eukaryotic elongation factor-2 and causes cessation of protein synthesis and cell death in vertebrate cells (Beattie and Merrill 1996; Beattie and others 1996; Yates and Merrill 2001), somehow originally had a benign function that degenerated to an inimical function after the Fall.

In summarizing a review article by Christopher Wren (Wren 2000), Wood writes that Wren “discusses three possible origins for bacterial pathogenicity” — lateral gene transfer, antigenic variation, and genomic decay. According to Wood, “Of these three themes, genomic decay is most consistent with the creationist idea of a degenerating creation” (Wood 2001: i). The Wren review shows that lateral gene transfer, antigenic variation, and genomic decay are trends observed in the genomic sequence data from pathogens. All three events are well documented in the literature and the completion of genomic sequences from pathogenic bacteria has extended our understanding of them. In other words, these events are not guesses about what makes microorganisms pathogenic, but are events for which we have solid genomic evidence.

Wood mentions these trends in the genomes of pathogenic bacteria because he thinks that the mycoplasmas demonstrate the best-documented case of pathogen-associated genome decay, even though members of the genus *Rickettsia* show pseudogenes and split genes, which are both signs of continuing genomic decay (Andersson and others 1998; Andersson and Andersson 1999a, 1999b; Ogata and others 2001). However, Wood also seems to accept that lateral gene transfer and antigenic variation are contributors to microbial pathogenesis. How appropriate is it to build a model of acquisition of pathogenesis that selects only one of these mechanisms while ignoring the other two?

Wood regards the mycoplasmas as a bacterial group that shows phylogenetic discontinuity from other bacteria because mycoplasmas lack a cell wall and use an atypical genetic code (Wood 2001: i-ii). Such a statement shows enormous disregard for earlier ribosomal RNA studies of mycoplasmas that clearly link them not only with some of the gram-positive eubacteria with genomes that contain low percentages of guanine and cytosine — which includes the *Bacillus/Lactobacillus* group (Lim and Sears 1989; Hori and others 1981; Maniloff 1983; Walker 1983; Rogers and others 1985) — but also specifically with a small subgroup of *Clostridia* represented by *Clostridium innocuum* and *Clostridium ramosum* (Woese and others 1985; Rogers and others 1985; Woese and others 1980).

Is the lack of a cell wall an adequate reason to consider the mycoplasmas phylogenetically discontinuous from the other eubacteria? The answer to this has to be no. Other bacteria lack cell walls. For example, the

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archaebacterium *Thermoplasma acidophilum* lacks a cell wall, but is completely unrelated to the mycoplasmas (Walker 1983; Woese and others 1980; Woese and Olsen 1986; Sanz and Amils 1988; Gaasterland 1999). Thus the lack of a cell wall by itself is not uniquely derived.

Furthermore, the ability of bacteria to lose their cell walls is well documented. Cell-wall deficient bacteria (CWDB), or "L-forms" as they are sometimes called, can appear under a variety of circumstances, and intensive antibiotic treatment can select for the formation of persistent L-forms that are resistant to antibiotics that attack cell wall synthesis (Domingue and Woody 1997).

Since the mycoplasmas tend to associate with insect, plant, or warm-blooded-animal cells, the loss of their cell wall is not that difficult to envision. The immune systems of these host organisms constantly search for foreign substances or antigens, and microorganisms that present fewer antigens are less easily recognized by the immune response. Since the cell walls of bacteria contain many potential antigens (Chatterjee 1997; Haslberger and others 2000; Heumann and others 1998; Ryan and others 2001), long-term association of bacteria with specific hosts could select for the generation of CWDB (Paton 1987; Sladek 1986).

Likewise, the origin of the alternative genetic code of some mycoplasmas is not as mysterious as it might initially appear. In some mycoplasmas, the codon UGA, which acts as a translational termination codon in most organisms, encodes the amino acid tryptophan, but besides this exception the genetic code of these organisms is completely standard. Mycoplasmal genomes contain low proportions of guanine (G) and cytosine (C) content, which means that their genomes show the effects of "AT-biased directional mutation pressure", which means that base substitutions in mycoplasmas consistently favor the replacement of C-G base pairs with

adenine-thymine (A-T) base pairs. Consequently, C-G-rich codons like CCN, GGN, GCN, or CGN (where N indicates any base) are rare in the coding regions of mycoplasmal genomes, and mycoplasmal proteins have fewer glycine, proline, alanine or arginine residues (see Table 1, p 25). In conserved proteins, mycoplasmas tend to have lysine residues, encoded by AAA and AAG, instead of the arginine residues, encoded by AGG, CGN, and AGA, found in the proteins of other bacteria (Razin and others 1998). Mitochondrial genomes sometimes use an alternative genetic code, and in this case it seems as though selection for a small genome streamlines the total number of tRNAs the genome encodes and favors the use of alternative codons (Knight and others 1999; Saccone and others 2000; Knight and others 2001). Here again the origin of an alternative genetic code is not mysterious (Osawa and others 1992). Therefore the insistence on discontinuity between the mycoplasmas and other eubacteria is almost certainly unwarranted.

organisms according to phylogeny, creationist classification schemes often suggest some taxonomic reorganization. Such rearrangements reflect the creationist belief that some organisms were created *ex nihilo* during the Creation Week and diverged since to produce extant organisms (Sarfati 1999). This emphasis on discontinuity between organisms motivated WJ ReMine to suggest a nomenclature for creationist taxonomy by adapting the term "baramin" coined by Frank Marsh in 1947 to refer to a "created kind". According to the nomenclature formulated by ReMine, a "holobaramin" is a "group containing all and only organisms related by common descent". An "apobaramin" is a "group of holobaramins that are separated from all other organisms by phylogenetic discontinuities". Finally, a "monobaramin" is "a group containing only organisms related by common descent, but not necessarily all of them" and a "polybaramin" is a group of organisms that do not share a common ancestor. ReMine gives the following examples to clarify his nomenclature: mammals are apobaraminic, the placental dogs are holobaraminic, but dogs and wolves are monobaraminic (ReMine 1990). It should be noted that this classification scheme still affirms that biological classification should reflect phylogenetic proximity.

In applying ReMine's nomenclature, Wood proposes that mycoplasmas compose an apobaramin. Since an apobaramin is a group of holobaramins that are separated from other organisms by phylogenetic discontinuities, the mycoplasmas must contain holobaramins. This designation is slightly problematic, since the typical criterion for a holobaramin is the ability to produce fertile offspring; since bacteria lack sexual reproduction, such a standard is unreasonable. Therefore the norm for designating a bacterial group as holobaraminic is somewhat arbitrary. Contemporary bacterial taxonomy often uses the percentage of DNA homology among bacterial genomes to distinguish among bacterial species, and such techniques determine phylogenetic sequences with some accuracy (Martin 2002).

Wood considers *Mycoplasma genitalium* and *Mycoplasma pneumoniae* to be members of the "same monobaramin". His reason for this is that the genome of *M. pneumoniae* contains all the genes found in the genome of *M. genitalium*, even in the same gene order. Furthermore, the genetic material unique to *M. pneumoniae* is localized to 6 segments of the genome bordered by repetitive sequences. Since the recombination-inducing protein RecA is encoded by the genome of *M. pneumoniae*, it is entirely conceivable that these *M. pneumoniae*-specific segments were deleted from the genome by RecA-dependent recombination to eventually form a genome that resembles that of *M. genitalium* (Himmelreich and others 1997).

While it is certainly reasonable to suggest that *M. genitalium* and *M. pneumoniae* are directly related by common descent, why should we exclude other mycoplasmas, since 16S rRNA analyses link other mycoplasmas, like *M. muris*, with *M. pneumoniae* (Weisburg and others 1989)? Also, these same studies definitively link the mycoplasmas to the gram-positive bacteria with low percentages of G-C base pairs, even though the mycoplasmas do show some diversity as a group (Woese and others 1985). These data suggest that

The best inference ... from these data is that the mycoplasmas evolved from a common ancestor.

the mycoplasmas are related to low G-C gram-positive bacteria and form a coherent, though diverse, phylogenetic unit. Such a close affinity with another bacterial group and the somewhat downsized nature of mycoplasmas is hardly coincidental. Certainly the best inference to draw from these data is that the mycoplasmas evolved from a common ancestor (Weisburg and others 1989; Maniloff 1983; Woese and others 1980). This makes their designation as "apobaraminic" highly questionable.

In discussing the sequenced *Mycoplasma* genomes, Wood uses outdated information. At its initial publication, workers thought that the genome of *M genitalium* contained 468 genes (Fraser and others 1995) and this is the number used by Wood. Since that time, however, further work and annotation have definitively shown that this was an underestimate. A global mutagenesis study published in 1999 has shown that the genome of *M genitalium* contains 480 protein-coding sequences and 517 total genes (Hutchison and others 1999). In addition, the genome of *M pneumoniae* does not encode the 677 genes that Wood quotes from the original reference (Himmelreich and others 1996). Instead, further annotation has shown that the genome of *M pneumoniae* encodes 688 proteins and 42 RNAs, for a grand total of 730 genes (Dandekar and others 2000). All of these studies were published before Wood's paper, but none is cited or discussed by him.

MYCOPLASMAS – MADE TO BE SMALL OR GOT SMALL AFTER GETTING MADE?

Because of their greatly reduced genomes, mycoplasmas lack a variety of biosynthetic genes, and Wood thinks that this is an important feature of their genomes. This leads to a potentially interesting question:

But how do we know whether the created ancestors of *M genitalium* or *M pneumoniae* had the ability to synthesize amino acids? Could the lack of amino acid synthesis genes be a design feature of this baramin? (Wood 2001: iii)

First of all, a lack of biosynthetic capacity is a common feature in many pathogenic bacteria, and genomic reduction is a hallmark of strict parasites (Andersson and others 1998; Ogata and others 2001; Fraser and others 1997; Fraser and others 1998; Kalman and others 1999; Stephens and others 1998; Read and others 2000). Therefore there is nothing unusual about the lack of biosynthetic machinery in the mycoplasmas.

Second, Wood never really answers the questions he posed above, even though he makes it clear that he thinks that *M genitalium* arose from *M pneumoniae* or an *M pneumoniae*-like organism. Therefore, we will answer them. According to contemporary evolutionary thinking, since bacteria arose before warm-blooded animals, all microorganisms that live on or inside animals had to evolve from free-living bacteria that eventually formed symbiotic relationships with warm-blooded animals. All organisms must have some kind of biosynthetic capacity in order to survive unless they are parasites and acquire all their nutrients from the host. Thus it makes sense to postulate that the ancestors of contemporary mycoplasmas almost certainly had some kind of biosynthetic capacity.

GENOMES BY THE LETTERS

The nitrogenous bases of the RNA and DNA nucleotides are usually referred to by their initials: A for adenine, T for thymine, U for uracil, C for cytosine, and G for guanine. Thus a DNA sequence that has a high proportion of adenine and thymine, for example, would be referred to as AT-rich.

From the creationist perspective, if mycoplasmas were originally created to inhabit the bodies of animals, then they might have already had reduced biosynthetic capacities, in the same way that organisms living in milk are unable to synthesize amino acids found in milk. Alternatively, mycoplasmas could have been created as free-living organisms that eventually became animal commensals and parasites.

Which of these hypotheses fits the evidence? According to Wood, the decay of the genomes of mycoplasmas fits the Creation/Fall model, since the Fall is the event that begins the cycle of degradation. However, genomic reduction as an adaptation to a parasitic lifestyle also fits the theory of evolution, and many obligate intracellular parasites show extensive genome reduction (Andersson and others 1998; Ogata and others 2001; Kalman and others 1999; Stephens and others 1998; Read and others 2000). Furthermore, the kinship the mycoplasma share with the *Clostridium* group is not a surprise for the evolutionary model, but it does pose some problems for the Creation/Fall model.

Another piece of data that fits the theory of evolution is that mycoplasmal genomes show signs of gene duplication as well as genomic degradation. The genome *M pneumoniae* shows duplication of the lipoprotein genes (Himmelreich and others 1997) and in the genome of *Ureoplasma urealyticum* there are 6 closely related iron transporter genes that apparently arose by means of gene duplication (Glass and others 2000). In addition, *Mycoplasma pulmonis* is capable of phase variation whereby it alters its outer membrane protein composition to escape detection by the immune system. The genome of *M pulmonis* contains several *variable surface antigen* or *usa* genes, and the number of *usa* genes varies between strains, thus demonstrating the occurrence of gene duplications within one species of *Mycoplasma* (Chambaud and others 2001).

Because mycoplasmas show reduced genomes, any gene duplications are probably indications of adaptations to a parasitic or commensal lifestyle. Other examples of obligate intracellular parasites with genomes that host both examples of gene decay and adaptive duplications are the *Rickettsia* (Ogata and others 2001). Gene duplications are examples of organisms' increasing the "information content" of their genomes, and they conflict with the creationist dictum that "mutations never add information but only reduce it" (Grigg 2000). Thus the evidence suggests that the mycoplasma not only downsized their genomes, but also reinforced other genes to make themselves better pathogens. This favors the evolutionary explanation for the origin of mycoplasmas, since the gene decay found in mycoplasmas does not occur alone, but in combination with gene duplications.

PARASITES – CREATION OR EVOLUTION?

Finally, Wood wishes to construct a framework for how



mycoplasmas became human parasites after the Fall. To do so, he compares his ideas with mainstream thoughts on the evolution of parasitism. Wood writes:

In the evolutionary model, pathogenicity and parasitism is thought to progress from very virulent (aggressive) forms to harmless or even mutually beneficial relationships. Advocates claim that natural selection will favor hosts that are resistant to the parasite and parasites that are not rapid killers of their own host environments. Thus as time progresses, the parasites evolve to less virulent forms and the hosts become tolerant of the more benign forms of the parasites (Wood 2001: iii).

Instead, Wood argues, God created the mycoplasmas as mutualists or commensals that became parasites after the Fall. The adaptation to parasitism included degradation of the mycoplasmal genome. Thus, the evolutionary scenario is challenged by the Creation/Fall model, which predicts just the opposite.

Unfortunately, the evolutionary story Wood tells is oversimplified. His reference for the concept of natural selection's decreasing virulence is a 13-year-old textbook (Pianka 1988). In the 1988 edition, Pianka qualifies this general expectation, writing: "In other situations, such as when a parasite finds itself engaged in a race against its host's immune response, selection may actually favor increased virulence" (Pianka 1988: 296). One must ask why Wood did not consult a more recent edition of Pianka, in which he would have found this revised discussion of the action of natural selection on virulence in parasitic organisms:

To the extent that natural selection favors evolution of reduced parasite virulence (see also subsequent discussion), parasite interactions may evolve gradually toward commensalisms and ultimately even become mutualistic interactions. Of course, selection could also proceed in the opposite direction (reverse arrows). Such changes may also occur during ecological time, as during the ontogeny of parasites (Pianka 1999: 323-5).

Pianka then gives examples of natural selection's decreasing virulence in the case of the myxoma and influenza viruses and increasing virulence in malarial parasites (Pianka 1999). Therefore the result of natural selection on the virulence of parasites is not a simple equation that applies to every case. Pianka closes this discussion with the statement "natural selection should favor levels of virulence for parasites with different types of transmission between hosts" (Pianka 1999: 325). Thus Wood has contrasted his own recent creationist view with an inaccurate rendition of contemporary evolutionary thinking regarding parasitism, which amounts to the construction of a straw man.

CONCLUSION

In conclusion, Wood's article does little to establish any evidence from sequenced bacterial genomes for recent creationism. His paper ignores the published data on mycoplasmal phylogenetics, creates a straw man of modern evolutionary thinking, and applies a taxonomic system that has no demonstrated efficacy in classifying

extant microorganisms. Further sequence data from other model organisms are forthcoming and it is likely that such data will only make the creationist case that much more difficult to accept.

REFERENCES

- Adam D. *Arabidopsis thaliana* genome. Now for the hard ones. *Nature* 2000; 408: 792-3.
- Adams MD, Celniker SE, Holt RA, Evans CA, Gocayne JD, Amanatides PG, Scherer SE, Li PW, Hoskins RA, Galle RF and others. The genome sequence of *Drosophila melanogaster*. *Science* 2000; 287: 2185-95.
- Andersson JO, Andersson SG. Insights into the evolutionary process of genome degradation. *Current Opinion in Genetics and Development* 1999a; 9 (6): 664-71.
- Andersson JO, Andersson SG. Genome degradation is an ongoing process in *Rickettsia*. *Current Opinion in Genetics and Development* 1999b; 16 (9): 1178-91.
- Andersson SG, Zomorodipour A, Andersson JO, Sicheritz-Ponten T, Alsmark UC, Podowski RM, Naslund AK, Eriksson AS, Winkler HH, Kurland CG. The genome sequence of *Rickettsia prowazekii* and the origin of mitochondria. *Nature* 1998; 396: 133-40.
- Arber W. Evolution of prokaryotic genomes. *Current Topics in Microbiology and Immunology* 2002; 264 (1): 1-14.
- Bargmann CI. Neurobiology of the *Caenorhabditis elegans* genome. *Science* 1998; 282: 2028-33.
- Beattie BK, Merrill AR. In-vitro enzyme activation and folded stability of *Pseudomonas aeruginosa* exotoxin A and its C-terminal peptide. *Biochemistry* 1996; 35: 9042-51.
- Beattie BK, Prentice GA, Merrill AR. Investigation into the catalytic role for the tryptophan residues within domain iii of *Pseudomonas aeruginosa* exotoxin A. *Biochemistry* 1996; 35: 15134-42.
- Blaxter M. *Caenorhabditis elegans* is a nematode. *Science* 1998; 282: 2041-6.
- Chambaud I, Heilig R, Ferris S, Barbe V, Samson D, Galisson F, Moszer I, Dybvig K, Wroblewski H, Viari A and others. The complete genome sequence of the murine respiratory pathogen *Mycoplasma pulmonis*. *Nucleic Acids Research* 2001; 29 (10): 2145-53.
- Clarke ND, Berg JM. Zinc fingers in *Caenorhabditis elegans*: Finding families and probing pathways. *Science* 1998; 282: 2018-22.
- Dandekar T, Huynen M, Regula JT, Ueberle B, Zimmermann CU, Andrade MA, Doerks T, Sanchez-Pulido L, Snel B, Suyama M and others. Re-annotating the *Mycoplasma pneumoniae* genome sequence: Adding value, function and reading frames. *Nucleic Acids Research* 2000; 28 (17): 3278-88.
- Domingue GJ Sr, Woody HB. Bacterial persistence and expression of disease. *Clinical Microbiological Review* 1997; 10 (2): 320-44.
- Doolittle RF. Biodiversity: Microbial genomes multiply. *Nature* 2002; 416: 697-700.
- Fraser CM. The Institute for Genomic Research (TIGR), Comprehensive Microbial Resource (CMR). 2002; available at <<http://www.tigr.org/tigr-scripts/CMR2/CMRHomePage.spl>>. Last accessed July 11, 2002.
- Fraser CM, Casjens S, Huang WM, Sutton GG, Clayton R, Lathigra R, White O, Ketchum KA, Dodson R, Hickey EK and others. Genomic sequence of a Lyme disease spirochaete, *Borrelia burgdorferi*. *Nature* 1997; 390: 580-6.
- Fraser CM, Gocayne JD, White O, Adams MD, Clayton RA, Fleischmann RD, Bult CJ, Kerlavage AR, Sutton G, Kelley JM and others. The minimal genome complement of *Mycoplasma genitalium*. *Science* 1995; 270: 397-404.
- Fraser CM, Norris SJ, Weinstock GM, White O, Sutton GG, Dodson R, Gwinn M, Hickey EK, Clayton R, Ketchum KA and others. Complete genome sequence of *Treponema pallidum*, the syphilis spirochete. *Science* 1998; 281: 375-88.
- Futuyma DL. *Evolutionary Biology*. Sunderland (MA): Sinauer Associates, 1998.
- Gaasterland T. Archaeal genomics. *Current Opinion in Microbiology* 1999; 2 (5): 542-7.
- Gibson G, Muse SV. *A Primer of Genomic Science*. Sunderland (MA): Sinauer Associates, 2002.
- Glass JI, Lefkowitz EJ, Glass JS, Heiner CR, Chen EY, Cassell GH. The complete sequence of the mucosal pathogen *Ureaplasma urealyticum*. *Nature* 2000; 407: 757-62.
- Goff SA, Ricke D, Lan TH, Presting G, Wang R, Dunn M, Glazebrook J, Sessions A, Oeller P, Varma H and others. A draft sequence of the rice genome (*Oryza sativa* L. ssp. japonica). *Science* 2002; 296: 92-100.
- Goffeau A, Barrell BG, Bussey H, Davis RW, Dujon B, Feldmann H, Galibert F, Hoheisel JD, Jacq C, Johnston M and others. Life with 6000 genes. *Science* 1996; 274: 546, 563-7.
- Grigg R. A brief history of design. *Creation Ex Nihilo* 2000; 22 (2): 50-3.



- Hacker J, Blum-Oehler G, Muhlendorfer I, Tschape H. Pathogenicity islands of virulent bacteria: Structure, function and impact on microbial evolution. *Molecular Microbiology* 1997; 23 (6): 1089-97.
- Hacker J, Kaper JB. Pathogenicity islands and the evolution of microbes. *Annual Review of Microbiology* 2000; 54: 641-79.
- Haslberger AG, Kohl G, Felnerova D, Mayr UB, Fürst-Ladani S, and others. Activation, stimulation and uptake of bacterial ghosts in antigen presenting cells. *Journal of Biotechnology* 2000; 83(1-2): 57-66.
- Henderson B, Poole S, Wilson M. Bacterial modulators: A novel class of virulence factors which cause host tissue pathology by inducing cytokine synthesis. *Microbiology Review* 1996; 60 (2): 316-41.
- Heumann D, Glauser MP, Calandra T. Molecular basis of host-pathogen interaction in septic shock. *Current Opinion in Microbiology* 1998; 1: 49-55.
- Himmelreich R, Hilbert H, Plagens H, Pirkel E, Li BC, Herrmann R. Complete sequence analysis of the genome of the bacterium *Mycoplasma pneumoniae*. *Nucleic Acids Research* 1996; 24 (22): 4420-49.
- Himmelreich R, Plagens H, Hilbert H, Reiner B, Herrmann R. Comparative analysis of the genomes of the bacteria *Mycoplasma pneumoniae* and *Mycoplasma genitalium*. *Nucleic Acids Research* 1997; 25 (4): 701-12.
- Hori H, Sawada M, Osawa S, Murao K, Ishikura H. The nucleotide sequence of 5S rRNA from *Mycoplasma capricolum*. *Nucleic Acids Research* 1981; 9 (20): 5407-10.
- Hutchison CA, Peterson SN, Gill SR, Cline RT, White O, Fraser CM, Smith HO, Venter JC. Global transposon mutagenesis and a minimal *Mycoplasma* genome. *Science* 1999; 286: 2165-9.
- Kalman S, Mitchell W, Marathe R, Lammel C, Fan J, Hyman RW, Olinger L, Grimwood J, Davis RW, Stephens RS. Comparative genomes of *Chlamydia pneumoniae* and *C. trachomatis*. *Nature Genetics* 1999; 21 (4): 385-9.
- Kathariou S. *Listeria monocytogenes* virulence and pathogenicity, a food safety perspective. *Journal of Food Protection* 2002; 65 (11): 1811-29.
- Knight J. All genomes great and small. *Nature* 2002; 417: 374-6.
- Knight RD, Freeland SJ, Landweber LF. Selection, history and chemistry: the three faces of the genetic code. *Trends in Biochemical Sciences* 1999; 24 (6): 241-7.
- Knight RD, Landweber LF, Yarus M. How mitochondria redefine the code. *Journal of Molecular Evolution* 2001; 53 (4-5): 299-313.
- Lander ES, Linton LM, Birren B, Nusbaum C, Zody MC, Baldwin J, Devon K, Dewar K, Doyle M, FitzHugh W and others. Initial sequencing and analysis of the human genome. *Nature* 2001; 409: 860-921.
- Law D, Chart H. Enterococcal *Escherichia coli*. *Journal of Applied Microbiology* 1998; 84 (5): 685-97.
- Lim PO, Sears BB. 16S rRNA sequence indicates that plant-pathogenic mycoplasma-like organisms are evolutionarily distinct from animal mycoplasmas. *Journal of Bacteriology* 1989; 171 (11): 5901-6.
- Lin X, Kaul S, Rounsley S, Shea TP, Benito MI, Town CD, Fujii CY, Mason T, Bowman CL, Barnstead M and others. Sequence and analysis of chromosome 2 of the plant *Arabidopsis thaliana*. *Nature* 1999; 402: 761-8.
- Maniloff J. Evolution of wall-less prokaryotes. *Annual Review of Microbiology* 1983; 37: 477-99.
- Martin AP. Phylogenetic approaches for describing and comparing the diversity of microbial communities. *Applied Environmental Microbiology* 2002; 68 (8): 3673-82.
- Mayer K, Schuller C, Wambutt R, Murphy G, Volckaert G, Pohl T, Dusterhoft A, Stiekema W, Entian KD, Terry N and others. Sequence and analysis of chromosome 4 of the plant *Arabidopsis thaliana*. *Nature* 1999; 402: 769-77.
- Myers EW, Sutton GG, Delcher AL, Dew IM, Fasulo DP, Flanagan MJ, Kravitz SA, Mobarry CM, Reinert KH, Remington KA and others. A whole-genome assembly of *Drosophila*. *Science* 2000; 287: 2196-204.
- Ogata H, Audic S, Renesto-Audiffren P, Fournier PE, Barbe V, Samson D, Roux V, Cossart P, Weissenbach J, Claverie JM and others. Mechanisms of evolution in *Rickettsia conorii* and *R. prowazekii*. *Science* 2001; 293: 2093-8.
- Osawa S, Jukes TH, Watanabe K, Muto A. Recent evidence for evolution of the genetic code. *Microbiological Reviews* 1992; 56 (1): 229-64.
- Paton AM. L-Forms: Evolution or revolution? *Journal of Applied Bacteriology* 1987; 63 (5): 365-71.
- Pianka ER. *Evolutionary Ecology*, 4th ed. New York: Harper and Row, 1988.
- Pianka ER. *Evolutionary Ecology*, 6th ed. San Francisco: Benjamin Cummings, 1999.
- Potempa J, Banbula A, Travis J. Role of bacterial proteinases in matrix destruction and modulation of host responses. *Periodontology* 2000; 24: 153-92.
- Razin S, Yegorov D, Naot Y. Molecular biology and pathogenicity of mycoplasmas. *Microbiology and Molecular Biology Reviews* 1998; 62 (4): 1094-156.
- Read TD, Brunham RC, Shen C, Gill SR, Heidelberg JF, White O, Hickey EK, Peterson J, Uitterback T, Berry K and others. Genome sequences of *Chlamydia trachomatis* MoPn and *Chlamydia pneumoniae* AR39. *Nucleic Acids Research* 2000; 28 (6): 1397-406.
- ReMine WJ. Discontinuity systematics: A new methodology of biosystematics relevant to the creation model. In: Walsh RE, Brooks CL, editors. *Proceedings of the Second International Conference of Creationism*. Volume 2. Pittsburgh: Creation Science Fellowship, 1990. p 207-13.
- Rogers MJ, Simmons J, Walker RT, Weisburg WG, Woese CR, Tanner RS, Robinson IM, Stahl DA, Olsen G, Leach RH and others. Construction of the mycoplasma evolutionary tree from 5S rRNA sequence data. *Proceedings of the National Academy of Sciences USA* 1985; 82 (4): 1160-4.
- Ruvkun G, Hobert O. The taxonomy of developmental control in *Caenorhabditis elegans*. *Science* 1998; 282: 2033-41.
- Ryan EJ, Daly LM, Mills KHG. Immunomodulators and delivery systems for vaccination by mucosal routes. *Trends in Biotechnology* 2001; 19 (8): 293-330.
- Saccone C, Gissi C, Lanave C, Larizza A, Pesole G, Reyes A. Evolution of the mitochondrial genetic system: An overview. *Gene* 2000; 261 (1): 153-9.
- Salanoubat M, Lemcke K, Rieger M, Ansong W, Unseld M, Fartmann B, Valle G, Blocker H, Perez-Alonso M, Obermaier B and others. Sequence and analysis of chromosome 3 of the plant *Arabidopsis thaliana*. *Nature* 2000; 408: 820-2.
- Sanz JL, Amils R. Archaeobacteria: Their phylogenetic relationship with the eubacterial and eukaryotic kingdoms. *Microbiologia* 1988; 4 (1): 5-27.
- Sarfati J. *Refuting Evolution*. Green Forest (AR): Master Books; 1999.
- Sladek TL. A hypothesis for the mechanism of mycoplasma evolution. *Journal of Theoretical Biology* 1986; 120 (4): 457-65.
- Stephens RS, Kalman S, Lammel C, Fan J, Marathe R, Aravind L, Mitchell W, Olinger L, Tatusov RL, Zhao Q and others. Genome sequence of an obligate intracellular pathogen of humans: *Chlamydia trachomatis*. *Science* 1998; 282 (5389): 754-9.
- Tabata S, Kaneko T, Nakamura Y, Kotani H, Kato T, Asamizu E, Miyajima N, Sasamoto S, Kimura T, Hosouchi T and others. Sequence and analysis of chromosome 5 of the plant *Arabidopsis thaliana*. *Nature* 2000; 408: 823-6.
- Theologis A, Ecker JR, Palm CJ, Federspiel NA, Kaul S, White O, Alonso J, Altavi H, Araujo R, Bowman CL and others. Sequence and analysis of chromosome 1 of the plant *Arabidopsis thaliana*. *Nature* 2000; 408 (6814): 816-20.
- Tully JG, Bové JM, Laigret F, Whitcomb RE. Revised taxonomy of the class *Mollicutes*: Proposed elevation of a monophyletic cluster of arthropod-associated mollicutes to ordinal rank (*Entomoplasmatales* ord nov), with provision for familial rank to separate species with nonhelical morphology (*Entomoplasmataceae* fam nov) from helical species (*Spiroplasmataceae*), and emended descriptions of the order *Mycoplasmatales*, family *Mycoplasmataceae*. *International Journal of Systematic Bacteriology* 1993; 43: 378-85.
- Venter JC, Adams MD, Myers EW, Li PW, Mural RJ, Sutton GG, Smith HO, Yandell M, Evans CA, Holt RA and others. The sequence of the human genome. *Science* 2001; 291: 1304-51.
- Walker RT. Mycoplasma evolution: A review of the use of ribosomal and transfer RNA nucleotide sequences in the determination of phylogenetic relationships. *Yale Journal of Biology and Medicine* 1983; 56 (5-6): 367-72.
- Weisburg WG, Tully JG, Rose DL, Petzel JP, Oyaizu H, Yang D, Mandelco L, Sechrest J, Lawrence TG, Van Etten J and others. A phylogenetic analysis of the mycoplasmas: Basis for their classification. *Journal of Bacteriology* 1989; 171 (12): 6455-67.
- Woese CR, Maniloff J, Zablen LB. Phylogenetic analysis of the mycoplasmas. *Proceedings of the National Academy of Sciences USA* 1980; 77 (1): 494-8.
- Woese CR, Olsen GJ. Archaeobacterial phylogeny: Perspectives on the urkingdoms. *Systematic and Applied Microbiology* 1986; 7: 161-77.
- Woese CR, Stackebrandt E, Ludwig W. What are mycoplasmas: The relationship of tempo and mode in bacterial evolution. *Journal of Molecular Evolution* 1985; 21 (4): 305-16.
- Wood TC. Genome decay in the Mycoplasmas. *Impact* 2001; 340: i-iv.
- Wood V, Gwilliam R, Rajandream MA, Lyne M, Lyne R, Stewart A, Sgouras J, Peat N, Hayles J, Baker S, and others. The genome sequence of *Schizosaccharomyces pombe*. *Nature* 2002; 415: 871-80.
- Wren BW. Microbial genome analysis: Insights into virulence, host adaptation and evolution. *Nature Review Genetics* 2000; 1 (1): 30-9.
- Yates SP, Merrill AR. A catalytic loop within *Pseudomonas aeruginosa* exotoxin A modulates its transferase activity. *Journal of Biological Chemistry* 2001; 276: 35029-36.
- Yu J, Hu S, Wang J, Wong GK, Li S, Liu B, Deng Y, Dai L, Zhou Y, Zhang X and others. A draft sequence of the rice genome (*Oryza sativa* L. ssp indica). *Science* 2002; 296: 79-92.

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BOOKREVIEWS

WHO WROTE THE BOOK OF LIFE? A HISTORY OF THE GENETIC CODE

by Lily E Kay.
Stanford (CA): Stanford University Press, 2000. 472 pages.

Reviewed by Jeffrey M Otto

According to the book jacket, this book consists of "a detailed history of one of the most important and dramatic episodes in modern science, recounted from the novel vantage point of the dawn of the information age and its impact on representations of nature heredity and society. Drawing on archives, published sources and interviews, the author situates work on the genetic code (1953-70) within the history of life science, the rise of communication technosciences (cybernetics, information theory and computers), the intersection of molecular biology with cryptanalysis and linguistics, and the social history of postwar Europe and the United States." This is an accurate, but incomplete, description of the book. In addition, and perhaps more importantly, the book is a discourse on why the author believes that the genetic code is not really a *code* in the true sense of the word, and why DNA contains chemical and biological specificity but not information *per se*. In the first chapter, she writes:

My thesis is that molecular biologists used "information" as a metaphor for biological specificity. However, "information" is a metaphor of a

metaphor and thus a signifier without a referent, a *cat-achresis*. As such, it became a rich repository for the scientific imaginaries of the genetic code as an information system and a Book of Life. The information discourse and the scriptural representations of life were inextricably linked. Metaphors, as I will examine, are ubiquitous in science, but not all metaphors are created equal. Some, like the information and code metaphors, are exceptionally potent due to the richness of their symbolisms, their synchronic and diachronic linkages and their scientific and cultural valences (p 2).

After reading the book jacket, the preface and the first chapter, one is left with the question "Who is the target audience for this book?" As best I can tell, it is aimed at professional science historians. The writing is too difficult and unfriendly to be aimed at the amateur science history enthusiast. Furthermore, the author assumes that the reader already is familiar with the history and the individuals involved. A simple, limited biography on each of the key individuals at the end of the text would have gone a long way to help the reader. It is likely that a neophyte enthusiast who managed to maintain interest while wading through the difficult text would quickly be confused and frustrated by the constant infusion of new names, all without adequate introduction.

Yet I cannot imagine that the professional science historians would be much interested in this book either. The author's approach seems to be more fragmented than unified in her attempt to link molecular biology, linguistics, informa-

tion theory, and yes, her own personal philosophy into this historical account of the unraveling of the genetic code. Had Kay restricted herself to describing the history of the unraveling of the genetic code, the text would have been much more accessible. This is all the more disappointing because the source material is rich and varied, consisting of quotes, letters, interviews, photographs, and drawings. It is unfortunate that Kay places such a large burden on her reader, expecting that the reader can pull together the salient details and form a coherent picture of this compelling and world-changing story with little help from the author.

While the writing style and her decision to focus on so many disciplines make the book a difficult read, it is actually her apparent philosophy on the nature of information and its relationship with DNA that I have the most problem with. Interwoven with Kay's description of the insights, experimentations, and technology that resulted in the discovery of the genetic code is her description of the researchers' struggle to reconcile their viewpoints on linguistics and information technology with their laboratory observations. On one end of the spectrum is the view that the "genetic code" is nothing of the kind; rather, it is a metaphor for biological specificity. At the other end of the spectrum is the view that the "genetic code" is actually the language for life, complete with all of its spiritual and scriptural qualities.

Kay, judging from her thesis statement in chapter 1 as well as her discussion in the conclusion, is a supporter of the first view. In a sense, her view, or others' for that matter, should not really matter. Whether one believes that the genetic code is a representation of the "Word of God" or that it is merely a representation for the biological specificity necessary for life, this belief does not change what it is. In the process of learning about or trying to understand something, we naturally liken things to one another. We relate the unfamiliar to the familiar and then document the differences. "'This' is like 'that' except for the following differences."

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Thus, in trying to understand how a section of DNA relates to a specific protein, some researchers found similarities to a code, while others found similarities to a language, and others found similarities to neither. What I have to take issue with is Kay's assertion that DNA does not really contain information; rather, it represents biological specificity. In her conclusion, she argues for this by pointing out that despite our knowledge and understanding of the genetic code, science has been largely unsuccessful in understanding what we have read: being able to distinguish coding and non-coding sequences, being able to sort out the plethora of polygenic disorders, and finding any true promise in the field of gene therapy. This philosophy smells too much to me like that of the creationist: "Life (or some feature of it) is too complex to have evolved on its own. Therefore God (or some other designer) must have designed it." Kay seems to be arguing that because today we do not have all the answers, because we are not "fully literate in the language of DNA" (to use a different metaphor), that DNA does truly contain information.

In my opinion, DNA does contain information, information that directs a cell in how it should operate and behave. Today, when given an mRNA sequence, computer programs without the aid of human intervention can read that sequence and give the amino acid sequence of the resulting protein. Additional progress has been made in identifying signals for intron-exon junctions, transcriptional start and stop sites, and other regulatory signals. Today, our understanding of these sequences, this DNA information, is incomplete. Our understanding is even more limited when we consider the global landscape of the genome. How does a cell know which regions of the genome to leave active, while silencing others? How is development regulated? We understand that there is a dizzyingly complex series of feedback loops, where DNA, RNA, protein, carbohydrates, fats, and a variety of small organic molecules all interact for the survival or death of the cell, tissue, organ, and organ-

ism. The information for these interactions, the instruction set, is all contained in the DNA. Our knowledge and understanding of this information is currently imperfect and incomplete. The complexity that results from the interactions between the cellular (and extracellular) components makes it difficult to tease out the necessary signals and information. This results in a "chicken or egg" sort of paradox. Again, regardless of what one's view is, it does not change the way things actually are. To deny that DNA contains information, based on our current inability to use it to describe life, is simply shortsighted.

In the end, I cannot recommend this book. Although I am impressed with the thoroughness and completeness of her research, I find that the process of bringing these ideas together has resulted in text that is unnecessarily dense

and that ultimately falls far short of the promise inherent in this naturally compelling story.

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CHARLES DARWIN: THE POWER OF PLACE

by Janet Browne.
New York: Knopf, 2002.
624 pages.

Reviewed by John C Greene

Readers who were enchanted with the first volume of Janet Browne's biography of Darwin will be equally pleased with this one. Here again Browne presents Darwin as the central figure in an

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Intelligent Design Creationism and Its Critics

Philosophical, Theological, and Scientific Perspectives

edited by Robert T. Pennock

The last decade saw the arrival of a new player in the creation/evolution debate—the intelligent design creationism (IDC) movement, whose strategy is to act as "the wedge" to overturn Darwinism and scientific naturalism. This anthology of writings by prominent creationists and their critics focuses on what is novel about the new movement.

The book contains articles previously published in specialized, hard-to-find journals, as well as new contributions. Each section contains introductory background information, articles by influential creationists and their critics, and in some cases responses by the creationists. The book concludes with Pennock's "Why Creationism Should Not Be Taught in the Public Schools."

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expanding circle of contexts: the context of family, of upper-middle-class gentry, of Whig politics and religious outlook in a rapidly industrializing nation, of British naval domination and colonial empire around the globe. Darwin himself appears as a wealthy country gentleman settled comfortably in his house at Downe, surrounded by family and servants, in close touch with his scientific friends by letter and by occasional visits, protected from unwanted social engagements and professional responsibilities by chronic poor health, devouring scientific books and journals, observing and experimenting on the potted plants, pigeons, bees, and earthworms in his study, gardens, aviary, and the surrounding countryside, enlisting the aid of his children, servants, plant and animal breeders, and correspondents foreign and domestic in his search for facts, facts, facts — which would support his “subversive” theory of evolution by natural and sexual selection.

When Alfred Russel Wallace sent him an essay setting forth a similar theory and asked his help in getting it published, Darwin was forced into action. Darwin’s friends Charles Lyell and Joseph Dalton Hooker arranged to have Wallace’s essay and some of Darwin’s unpublished writings — including a letter to the American botanist Asa Gray predating Wallace’s essay — read before the Linnaean Society and published in its journal. Relieved but shaken, Darwin went to work preparing an “Abstract” of the big species book entitled “Natural Selection” begun in May 1856. In November 1859, Darwin’s “Abstract” appeared in print under the title *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*.

Janet Browne’s account of Darwin’s style of presenting his argument (p 53-7) is a masterpiece of interpretation and analysis linking that style to Darwin’s gentlemanly personality, his use of well-known literary genres, his homely illustrations from the practical pursuits of gardeners and plant and animal breeders, his connections with leading men of science, and his implicit evocation of

the competitive ethos and secularizing appeal to natural law in an industrializing British nation. “And what a book it was”, writes Browne. “Few scientific texts have been so tightly woven, so packed with factual information and studded with richly inventive metaphor.”

As to Darwin’s mode of reasoning by analogy, Browne is certainly right that Darwin regarded the analogy between artificial and natural selection as “the best and safest clue” in unraveling the secrets of nature. In place of Aristotle’s analogy of nature as a well-run household economy, Darwin proposed the metaphor of “natural selection” — evoking both progressive British scientific agriculture and the competitive market economy extolled by Adam Smith. But whether Darwin’s metaphor was intended to suggest a godless probabilistic universe governed by “irregular, unpredictable contingencies”, by “statistics and chance”, as Browne seems to suggest (p 56, 283), seems doubtful. Although Darwin’s theory can be seen in retrospect as requiring a revised philosophy of science, Darwin himself seems to have tried to be a good Newtonian scientist. In his big pre-*Origin* species book, he defined nature as “the laws established by God to govern the universe” — “his most magnificent laws” he had called them in his notebooks. In the *Origin* these became “the laws impressed on matter by the Creator”, the succession of organic forms produced by them “ennobled” in the light of Darwin’s theory.

Nor was Darwin’s view of nature as “bleak” as Browne depicts it. He believed that natural selection brought about gradual organic “improvement”, not simply adaptation. The more evolved forms tended to be “improved” forms. “If I have a second edition”, he wrote to Lyell in 1860, “I will reiterate ‘Natural Selection’ and, as a general consequence, Natural Improvement.” And he could sound like an evolutionized William Paley when, as in the closing paragraph of the chapter on “The Struggle for Existence”, he reflected that “we may console ourselves with the full belief that

the war of nature is not incessant, that no fear is felt, that death is generally prompt, and that the vigorous, the healthy, and the happy survive and multiply.”

Having led her readers through the *Origin*, Browne gives a stirring account of how Darwin from his study, largely by correspondence, orchestrated the campaign to ensure its favorable reception, sending copies to his foreign correspondents and superintending arrangements for translations, combing the reviews, cheering on Huxley, Lyell, Hooker, Gray, and others in their efforts to assist him, and paying for republication in pamphlet form of favorable reviews. “Darwin’s opponents”, Browne writes, “failed to achieve anything like the same command of the media or penetration of significant institutions. Within a year after publication, it was nearly impossible to break into Darwin’s tightly integrated group without some express homage to evolution.”

In Part II of Browne’s second volume, devoted to the 1860s, we see Darwin alternately at work on the successive revised editions of the *Origin*, on his beloved sun-dews, orchids, and Venus fly traps, on two fat volumes on variation under domestication (containing his ill-fated theory of heredity called “pangenesis”), and on the growing anthropological and archaeological literature concerning cultural evolution, until overwork ruined his health and aged him noticeably. Janet Browne weaves the story of these years skillfully, empathizing with Darwin’s love of observing and experimenting on plants, noting how all his research was directed toward vindicating his theory of evolution by natural selection, how that theory and Malthusian political economy were part of a common cultural context, how Darwin’s *Origin* was received by philosophers, philologists, literary figures, American transcendentalists and Unitarians, and by scientists such as Alfred Russel Wallace and his erstwhile traveling companion in Brazil Henry Walter Bates, and, finally, how science had become Darwin’s lifeline. “Without this, he had ‘nothing’ to make his life worth living.”



As the post-*Origin* decade drew to a close, Browne explains, Darwin felt compelled to publish his views on human evolution — views he had feared to make known, hoping that Lyell or Wallace would step forward. Determined to defend his theories, Darwin began work on the book which, after considerable negotiation with his publisher, bore the title *The Descent of Man and Selection in Relation to Sex*.

In her discussion of this, the most revolutionary of Darwin's books, Browne cannot muster the same enthusiasm she displays in her account of the *Origin*. Darwin, she says, was trying to do too many different things — the natural history and lineage of mankind, the mental faculties of animals and humans, the origin of language, morals, and music, sexual selection in animals and humans, and the human progress from savagery to civilization. Browne reports Darwin's views on these subjects mostly without comment, although she obviously has reservations about some of these views. We learn that Darwin thought that language had emerged gradually from the vocalizations of apes, that religious belief was nothing more than a primitive urge to bestow a cause on otherwise inexplicable natural events, that moral values were relative, that there had been a progressive advance in moral sentiment ("the 'higher' values were, for him, ... the values of his own class and nation"), that "although he rejected the outward trappings of the established Anglican religion, he subscribed wholeheartedly to its underlying values and presumed the onward march of civilization", that men possessed an innate intellectual superiority over women, and that his theory of sexual selection could explain not only the diverging physiques and behavior patterns of males and females but also the origin of human geographical diversity, perhaps even the foundations of human civilization itself.

The theory of sexual selection, Browne declares, lay at the center of his argument concerning human evolution. Why Darwin should have devoted more than half of his book on humans to sexual selection in non-human animals remains

unexplained. Browne suggests that Darwin was making an analogy to artificial selection, in which "breeders chose traits for 'use or ornament,' imposing their own taste or judgment on organisms".

But Darwin was not done with humans. No sooner was the *Descent* published than he resumed his studies on the expression of emotion in humans and nonhuman animals — the third and final link in the merging of human and animal evolution which Darwin had envisaged in his 1830s notebooks. Once again, through Browne's fluent prose, we see Darwin ransacking his old notes, studying the expressions of children and domestic pets, firing letters in every direction, contacting directors of lunatic asylums and medical and art photographers for photographs to illustrate his thesis. "The expressions that pass over human faces", writes Browne, "were, to him, a daily, living proof of animal ancestry." And it struck a responsive chord in his readers. *The Expression of the Emotions in Man and Animals* sold very well.

In Browne's last 3 chapters, we see Darwin returning to his beloved botanical studies and his earthworms, enjoying *Punch's* ape-man cartoons, managing a stream of visitors with the aid of his family and friends, answering letters inquiring about his religious views without equivocation ("these were the most godless years of his life"), promoting his sons' careers, accepting the honors bestowed upon him with due modesty, promoting the cause of science in every way he could, and, in May 1876, beginning work on an autobiography. In Browne's view, Darwin, for all his brilliance in analyzing scientific problems, was not good at self-analysis. "He was", she says, "constructing himself not as a person, living and growing, but as a series of publications, an author." Only on the subject of religion did he drop his self-protective guard. He seemed, says Browne, to accept loss of faith as an inevitable feature of the life of a scientist. "No other experiences, he implied, could match those he encountered in science." Inward conviction of God's existence could not be trusted, nor could he trust his own reason in

the matter, knowing that his mental faculties were developed from "a mind as low as that possessed by the lowest animal."

Although Darwin could not know it, at the same time that he was writing his autobiography, Arthur James Balfour was hard at work on a book entitled *A Defence of Philosophic Doubt. Being an Essay on the Foundations of Belief*. This book, published in 1879, contained a searching critique of the positivistic, agnostic, empiricist philosophy of science and nature advocated by John Stuart Mill, Herbert Spencer, John Tyndall, and others, and proposed instead that both science and theology were attempting to represent in human terms a reality transcending the power of human thought to imagine correctly or grasp fully. In 1895, in his next book *Foundations of Belief*, Balfour extended his critique to embrace Darwin's evolutionary naturalism, arguing that it deprived the Victorian values cherished by Darwin, Huxley, and Balfour himself of any rational foundation, thereby undercutting the foundations of Western civilization. Huxley, then struggling with his final illness, mustered enough strength to defend agnosticism and predict the eventual triumph of the scientific spirit over Judaeo-Christian obscurantism. The debate over evolutionary naturalism thus begun is still with us. One wonders what Darwin's position would be in the light of twentieth-century developments in science, warfare, and Western culture.

Janet Browne's biography does not raise these questions. But no one has described Darwin in his Victorian context better or more engagingly than she. Her prose is well-nigh perfect, her research exhaustive, her powers of empathy remarkable, her 24 pages of illustrations fascinating and illuminating, her judgments well balanced. Darwin could not have asked for a more sympathetic, discerning, and thorough biographer.

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