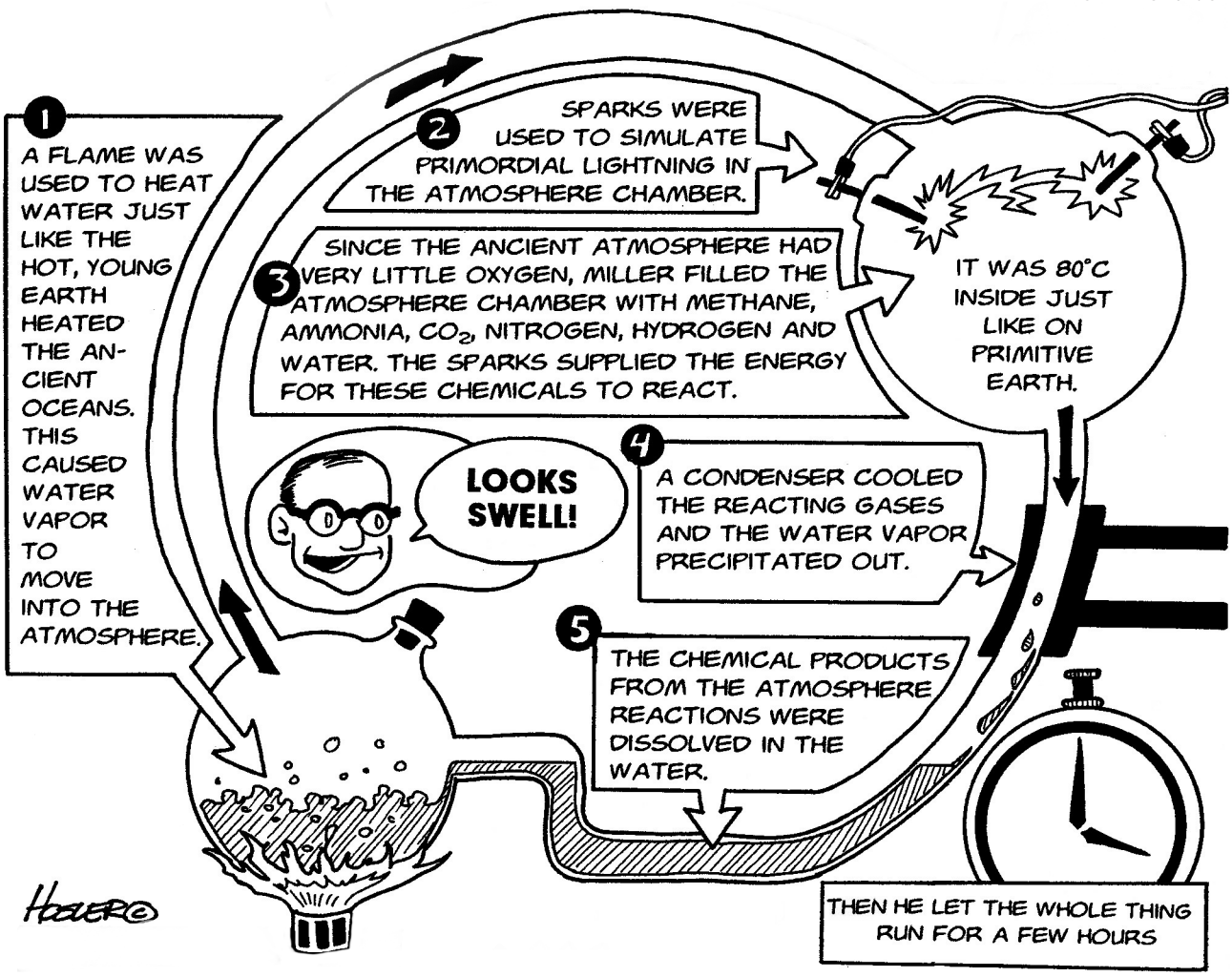
REPORTS OF THE NATIONAL CENTER FOR SCIENCE EDUCATION

DEFENDING THE TEACHING OF EVOLUTION IN THE PUBLIC SCHOOLS

Volume 23, Numbers 3-4 **MAY–AUG, 2003**

CONTINUES *NCSE REPORTS* & *CREATION/EVOLUTION*



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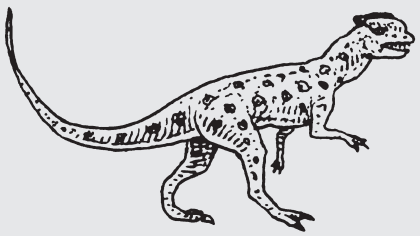

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VOLUME 23, NR 3-4, MAY–AUG 2003
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Cover Illustration:
Detail from Jay Hosler's "The scary story";
see p 27.

One of the most common "arguments against" evolution is the supposed improbability of a completely naturalistic origin of the first living organism. While most of those arguments are based on a serious misunderstanding — and sometimes an active misrepresentation — of the models for the emergence of the first life, there is one nugget of truth in them: there is no single accepted model for how the first life appeared on earth. But, of course, the fact that there are many competing naturalistic models for the origin of the first life on earth does not mean that there are no viable naturalistic models. Once again, anti-evolutionists misunderstand — or misconstrue — an unsettled field that abounds in exciting cutting-edge research marked by active debate as though it were a futile holding action against the more "reasonable" alternative of "intelligent design".

Of course, nothing could be further from the truth! The charges of anti-evolutionists that the resistance to ID is some sort of dogmatic closing of ranks does not square with the wide-ranging debate among the researchers working to understand how life first appeared on earth. Although there are a few basic themes in the various proposals, there is still quite a bit of disagreement among models. The ranks are anything but closed.

We take this special double issue of *RNCSE* to present feature articles and other resources related to the current research into the first life on earth — origin-of-life (OOL) research as it is called for short. This issue by no means provides complete or comprehensive coverage of this exciting field, but it does focus on two very important aspects of this research. First, David Deamer reviews a number of models for formation of the important components of living things and how these may have emerged on the early earth. Second, David Morrison illustrates how the search for organic compounds and organisms elsewhere in the universe may help us to understand how life emerged here on earth.

Connecting the nuts-and-bolts of OOL research with activism on behalf of evolution education, Andrew D Ellington and Matthew Levy recently told the Texas Board of Education that the Discovery Institute's criticism of the treatment of the origin of life in 11 textbooks under consideration is, in their words, "either completely wrong or misleading to the point of dishonesty."

On the lighter side, we are pleased to run a cartoon about OOL research by the talented Jay Hosler, whose *The Sandwalk Adventures* (Columbus [OH]: Active Synapse, 2002) is a lighthearted but accurate cartoon explanation of evolution; we plan to review it soon.

BETWEEN THE COVERS

Speaking of book reviews, we have saved up several specifically on OOL research for the Book Reviews section of this issue. We hope you enjoy Andrew Pohorille's review of *The Spark of Life* and Keith Ashman's review of *Origins of Existence.* Both books base their expositions in the laws of physics and chemistry that must have shaped the compounds that are essential to life. Paul Gross reviews Iris Fry's *The Emergence of Life on Earth,* which is even more broad-ranging than *The Spark of Life* or *Origins of Existence* — if that can be imagined. Finally, Danny Yee is back with a short review of the second edition of Freeman Dyson's *Origins of Life*. What all these books have in common — besides trying to understand naturalistic scientific models for the origin of life on earth — is a serious attempt to come to grips with the essential question for all OOL studies: an answer to the question, "What is life?"

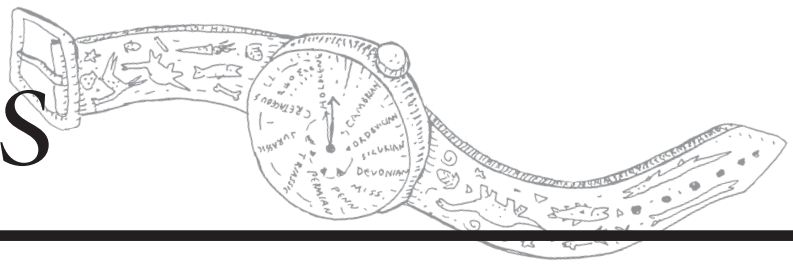
IN THE NEWS

The "Santorum Amendment" and the venerable language of the "Alabama disclaimer" do not seem to fade away. Our News and Updates sections tell us about actions in legislatures around the country to weaken evolution education. So far, these legislative actions have failed, but there have been several close calls.

In NCSE News, our members continue to do us proud. Many of you are very active in supporting and promoting evolution education and have told us about it. We know that many others of you are also quite active in your communities. Why not drop us a line and let us know what is happening in your part of the country?

RNCSE 23 (3–4) was printed in October 2003.

NEWS



Evolution Still OK in Oklahoma (For Now)

Eric Meikle
NCSE Outreach Coordinator

The Oklahoma Legislature dealt with evolution textbook disclaimers twice during its 2003 session. One proposal died quietly in committee, but another was nearly adopted, falling just one vote short of passage.

Disclaimers modeled on Alabama's 1995 textbook insert that cautioned students that evolution is "theory, not fact" have come up frequently in Oklahoma in the last few years both in the legislature and before the Oklahoma Textbook Committee, which in 1999 tried to require a disclaimer, but was prevented from doing so by a ruling of the state's attorney general (see *RNCSE* 1999 Sep/Oct; 19 [5]: 7–8, 1999 Nov/Dec; 19 [6]: 9, 11–2, and 2000 Jan–Apr; 20 [1–2]: 20–1). Kenneth R Miller's analysis of the proposed Oklahoma disclaimer appeared in *RNCSE* 2000 May/Jun; 20 (3): 30–3 (available on-line at <http://www.ncseweb.org/resources/articles/1910_dissecting_the_disclaimer_2_7_2001.asp>).

House Bill 1504, introduced by Representative Bill Graves (R–Oklahoma City) in the 2003 session of the legislature, would have written the very same disclaimer into law. HB 1504 was referred to the House Education Committee, but not considered further there, and the bill eventually died when the legislative session ended on May 30 (see *RNCSE* 2003 Jan/Feb; 23 [1]: 6–7 and 2003 Mar/Apr; 23 [2]: 12–4).

However, the House did adopt the disclaimer as an amendment to Senate Bill 346, which, when passed by the Senate, had nothing to do with teaching evolution. As the "Oklahoma Educator Protection Act", the purpose of SB 346 was to limit liability suits against educational entities (school boards, administrators, teachers, and staff). Although the bill was opposed by some teachers' groups and trial lawyers' associations, it was regarded as likely to pass.

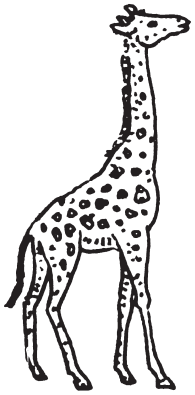
When SB 346 was considered by the House, however, Representative Opio Toure (D–Oklahoma City) proposed an amendment consisting of the same text as HB 1504. The House accepted Toure's

TEXT OF OKLAHOMA'S HB 1504

A. All textbooks used by school districts in the state in which evolution is discussed shall include the following disclaimer:

> This textbook discusses evolution, a controversial theory which some scientists present as scientific explanation for the origin of living things, such as plants and humans. No one was present when life first appeared on earth. Therefore, any statement about life's origins should be considered as theory, not fact. The word evolution may refer to many types of changes. Evolution describes changes that occur within a species, for example, white moths may evolve into gray moths. This process is microevolution which can be observed and described as fact. Evolution may also refer to the change of one living thing to another, such as reptiles into birds. This process, called macroevolution, has never been observed and should be considered a theory. Evolution also refers to the unproven belief that random, undirected forces produced a world of living things.
>
> There are many unanswered questions about the origin of life which are not mentioned in your textbook, including: Why did the major groups of animals suddenly appear in the fossil record, known as the Cambrian Explosion? Why have no new major groups of living things appeared in the fossil record in a long time? Why do major groups of plants and animals have no transitional forms in the fossil record? How did you and all living things come to possess such a complete and complex set of instructions for building a living body?
>
> Study hard and keep an open mind. Someday you may contribute to the theories of how living things appeared on earth.

B. The State Textbook Committee shall determine which textbooks shall include the disclaimer set forth in subsection A of this section. If the disclaimer is not printed in the textbook by the publisher, the State Textbook Committee shall be responsible for ensuring that the disclaimer is inserted into any textbook authorized for use in public schools of Oklahoma.



amendment, and then passed the revised bill by a vote of 92–9.

The bill then returned to the Senate, which first voted 22–19 to accept the disclaimer amendment, and then voted 23–17 to accept the revised bill. However, 25 votes were required for the bill to pass.

Later in the session, SB 346 was brought up for a final reconsideration. The vote was 24–20 in favor, still one vote short of the total required for passage. This was the end of the line for the disclaimer before the legislature adjourned.

Victor Hutchison, Cross Research Professor Emeritus in the Department of Zoology, University of Oklahoma, and a longtime observer of Oklahoma politics, sent NCSE these comments on the 2003 disclaimer legislation:

> Toure, a liberal representative of an Oklahoma City district, stated that he added the disclaimer amendment as a "poison pill" to guarantee defeat of the basic bill, SB 346. In Oklahoma, this is risky politics! Several Democrats in the Senate were instrumental in defeat of the base bill and the disclaimer, the latter having received more media attention. Senator Cal Hobson, president *pro tempore* of the Senate, was especially effective in convincing some reluctant members to support the leadership position to defeat the bill.
>
> Senator Bernest Cain said that legislation such as SB 346 "demeans the Senate. We're going to be the laughing stock of the country if we're going to come out with a bill that says you have to have a disclaimer in a science book that says anything about evolution one way or the other." Cain's office was then overwhelmed with telephone calls from fundamentalist Christian groups.
>
> The few Democratic senators who voted for the bill apparently did so because of fears of political repercussions from vocal fundamentalist Christian groups in their districts. As one of them said, "I can't vote against the disclaimer since my own pastor told me not to."
>
> Although Oklahomans opposed to evolution disclaimers prevailed by the most narrow of margins this year, we can expect similar attempts by creationists next year. It will require a really major effort in 2004 (a legislative election follows that session) to defeat the opponents of evolution again and for reason to prevail.

As always, NCSE is prepared to help Oklahomans to defend the teaching of evolution in their state's public schools.

UPDATES

Arkansas: Former Arkansas Governor Frank Durward White died in Little Rock on May 21, 2003, at the age of 69. It was White who, on March 19, 1981, signed Act 590, "The Balanced Treatment for Creation-Science and Evolution-Science Act", into law, prompting the *Arkansas Gazette*'s editorial cartoonist thereafter to draw him holding a peeled banana. A group of 23 Arkansas citizens and organizations subsequently challenged the constitutionality of Act 590; Judge William R Overton's decision in *Rev Bill McLean et al v Arkansas Board of Education*, handed down on January 5, 1982, was that the law was indeed unconstitutional. (For a collection of articles about *McLean*, see *Creationism, Science, and the Law: The Arkansas Case*, edited by Marcel Chotkowski La Follette, Cambridge [MA]: MIT Press, 1983.) The Associated Press's obituary for White described him as "widely remembered" for his role in the controversy.

Arkansas, Rogers: Angry that his granddaughter is learning about human evolution in her high school biology class, Bob Dunning, the pastor of Rocky Comfort Assembly of God, is advocating the removal of the topic from the Rogers Public Schools science curriculum (KHBS/KHOG-TV, 2003 Aug 21; available on-line at <http://www.thehometownchannel.com/news/2421920/detail.html>). "I wouldn't have a problem with them teaching that if they [gave us] equal time to teach creation, but they won't do that, because [they] don't want God brought in the subject", Dunning said. According to a report in the Fort Smith, Arkansas, *Times Record* (2003 Aug 21; available on-line at <http://www.swtimes.com/archive/2003/August/22/news/Pastor.html>), however, Dunning is asking only for a policy that allows students to be exempt from "specific instruction which conflicts with their religious beliefs"; at a school board meeting on August 19, 2003, he presented a model policy in use in the Phoenixville, Pennsylvania, school district. Janie Darr, Superintendent of the Rogers Public Schools, said at the board meeting that the school's attorney and officials of the state Department of Education agree that the board is not able to adopt a policy that would exempt students from state-required classwork. Dunning expects that his policy will be rejected at the next board meeting, in which case, he told the *Times Record*, he would not "be surprised" if a lawsuit were to be filed.

California, Roseville: The creationism/evolution controversy has returned to Roseville. In 2001, creationists lobbied for the addition of "intelligent design" during the adoption of district-wide science standards, but the Board of Trustees of the Roseville Joint Union High School District eventually voted 4–1 to include evolution without qualification (see *RNCSE* 2000 Nov/Dec; 20 [6]: 6–8). Creationists may have been emboldened to try again, now that two members of the board are openly hostile to evolution education. Kelly Lafferty, who favored creationism in 2001, has now been joined on the board

by president Jan Pinney, who told the *Sacramento Bee*, "I see so much evidence that evolution is bogus" (2003 Jul 3; available on-line at <http://www.sacbee.com/content/news/story/6966399p-7915508c.html>). The present debate was sparked by the board's decision to adopt a biology textbook that is silent about creationism; local parent Larry Caldwell originally asked for "intelligent design" to be added to the curriculum, but is now lobbying only for the inclusion of "evidence against evolution". Among the supplementary materials suggested at a meeting on July 1, 2003, were Jonathan Sarfati's *Refuting Evolution 2* (Green River [AR]: Master Books, 2002) and DVDs of the "intelligent design" videos *Unlocking the Mystery of Life* and *Icons of Evolution*. Look for further coverage of developments in Roseville in the next issue of *RNCSE*.

Colorado: In a survey of candidates for the Colorado State Board of Education in 2002, the Colorado division of the American Association of University Women asked each candidate, "What is your position on the teaching of intelligent design as an alternate [*sic*] to the theory of evolution in public schools?" (<http://www.coaauw.org/election2002/surveys.html>). Rico Munn (D), running in District 1, replied, "The theory of evolution is the leading scientific theory on the origin of the world. In cases where our knowledge is limited or speculative, we should strive to teach our children the leading scientific theories"; his opponent, Mel Hilgenberg (R), did not reply. Christine Pacheco-Koveleski (D), running in District 3, replied, "I believe that both positions can be taught side by side to respect the diverse views of the community on this complex subject"; her opponent, Pamela Suckla (R), replied in part, "I believe that to teach only the theory of evolution is wrong. I am not suggesting that we hold services in our schools or that we teach religion, that is also one's preference and a parental privilege, but I believe that at some level this must be taught." Christine Baca (D), running in District 7, replied, "The phrase 'intelligent design' reflects an explicitly religious concept, and should be clearly differentiated from scientific theory. The phrase essentially refers to creationism, which, being synonymous with "intelligent design", is not scientific theory either. While our public schools should encourage academic debate, it is not appropriate to use public tax dollars to promote one religion over another. I oppose teaching intelligent design as an alternative to the science of *de[s]cent with modification* (or 'biological evolution')" (emphasis in original). Her opponent, Glenn Rhoades (R), replied, "We need to start with the things we hold as verifiable truth regardless of worldviews. These fall into research-based curricula. These 'micro-evolution' or 'genetic traits' are verifiable and proven in labs around the world. After this it gets a little bit tricky. We cannot prove that there is large scale transformation into a new life form such as a reptile turning into a bird. As such I say that this is where you can freely teach evolution as a theory with that of an "intelligent design" theory if you treat all fairly without going into specific religious denominational views. It is when any theory is stated as fact that I start having problems." In the November 5, 2002, election, Munn, Suckla, and Baca won.

Kansas: On August 12, 2003, the Kansas Board of Education voted 7–3 to conduct a full-scale review of the state's science standards (*Topeka Capitol-Journal* 2003 Aug 13; available on-line at <http://www.cjonline.com/stories/081303/kan_evolution.shtml>). In July, the state's education commissioner reminded the board that a review of the standards is required by law; citing both the likely controversy over the treatment of evolution and the need for his staff to deal with issues concerning compliance with the No Children Left Behind Act, he recommended a less-than-full–scale review. The board deadlocked 5–5, with the members who support evolution education favoring a full-scale review, apparently in the hope that it would rally support for moderate candidates in the Republican primaries in the next election (*Dodge City Daily Globe* 2003 Jul 14; available on-line at <http://www.dodgeglobe.com/stories/071403/sta_0714030011.shtml>). The August vote represented a compromise: although the full-scale review will be conducted, the review committee will not be appointed until August 2004 and thus is unlikely to finish its work until well after the 2004 general election. Two moderate members, Carol Rupe and Bill Wagnon, broke ranks to vote for the compromise.

Kansas, Blue Valley: The creationism/evolution controversy played a role in the 2003 campaign for positions on the Blue Valley School Board. Five candidates — David Wolfram, Krista Salter, Bob Hayworth, Reneé Herman, and Maynard Ahner — were endorsed by, and apparently received support from, a group of conservative Republican state legislators, in what was described as unprecedented partisan intrusion from state lawmakers into nonpartisan local school board races (*The Johnson County Sun* 2003 March 13; available on-line at <http://www.zwire.com/site/news.cfm?newsid=7358636&BRD=1459&PAG=461&dept_id=155725&rfi=8>). The president of Kansas Families United for Education, Kathy Cook, said that, in their responses to a survey from KFUE, all of these candidates indicated that they believe that biblical creationism should be taught alongside evolution in science classes: "Getting creationism in through the back door is obviously the real agenda of this clique". All of the creationist candidates were defeated, by about a 70–30 margin in every case, in the April 1, 2003, election.

Kansas, Shawnee Mission: A creationist activist was in the news for protesting the viewing of the film *Inherit the Wind* (1960) in her daughter's biology class at Shawnee Mission East High School. Celtie Johnson, who was prominent in the furor following the August 1999 decision by the Kansas State Board of Education to remove key aspects of the theory of evolution from the state science standards, complained that *Inherit the Wind* "is 98 percent pure Hollywood fabrication ... just intentional offensive bigotry against Christians" (KMBC-TV, 2003 May 19, available on-line at <http://www.thekansascitychannel.com/news/2214087/detail.html>).

Johnson also contributed an op-ed to the *Kansas City Star* entitled "Movie is inherently just 'wind'" (2003 Jun 1; available on-line at <http://www. kansas. com/mld/kansascitystar/sports/high_school/center/5979749. htm>), explaining her opposition to the film. A committee appointed to review the use of the film recommended that *Inherit the Wind* remain in the school's library, but that it not be used in science classes due to its being both dated and potentially offensive (KMBC-TV, 2003 Jun 3, available on-line at <http://www.thekansascitychannel.com/education/2246260/detail.html>).

Louisiana: When the Louisiana legislature adjourned on June 23, 2003, three anti-evolution measures died: House Concurrent Resolution 50, House Bill 1782, and Senate Bill 1125. HCR 50 urged public school systems not to purchase textbooks "that do not present a balanced view of the various theories relative to the origin of life but rather refer to one theory as proven fact" (see *RNCSE* 2003 Mar/Apr; 23 [2]: 12–4). HB 1782 would have prohibited the state government "from knowingly printing or distributing material that contains information that is false or fraudulent"; a bill introduced in Arkansas in 2001 contained similar language as well as a host of standard creationist allegations about false and fraudulent claims in evolutionary biology (see *RNCSE* 2002 Nov/Dec; 22 [6]: 30–4). On April 30, HB 1782 was considered by the House of Representatives, which tabled it after a brief discussion. SB 1125 was introduced in the Senate on April 29 and referred to the Committee on Senate and Governmental Affairs, where it died when the legislature adjourned; it closely resembled HB 1782. Information about all three bills is available from the legislature's web site <http://www. legis.state.la.us/>.

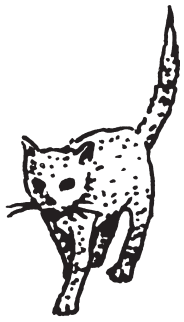
Michigan: On July 2, 2003, House Bill 4946 was introduced in the Michigan House of Representatives and referred to the Education Committee. HB 4946 would amend Michigan's school code to require the state board of education to modify its science standards to include the phrase "intelligent design of a Creator" wherever evolution is mentioned. HB 4946 was introduced by a member of the Education Committee, Representative Kenneth Bradstreet (R–District 105), and has 24 cosponsors, 8 of whom are also members of the 19-member committee. The relevant portion of HB 4946 reads as follows:

> (10) As soon as practicable after the effective date of this subsection, the state board shall revise the recommended model core academic curriculum content standards under subsection (2) as follows:
>
> In the science standards, all references to "evolution" and "how species change through time" shall be modified to indicate that this is an unproven theory by adding the phrase "All students will explain the competing theories of evolution and natural selection based on random mutation and the theory that life is the result of the purposeful, intelligent design of a Creator." In the science standards for middle and high school, all references to "evolution" and "natural selection" shall be modified to indicate that these are unproven theories by adding the phrase "Describe how life may be the result of the purposeful, intelligent design of a Creator."
>
> In the science standards for middle and high school, all references to "evolution" and "natural selection" shall be modified to indicate that these are unproven theories by adding the phrase "Explain the competing theories of evolution and natural selection based on random mutation and the theory that life is the result of the purposeful, intelligent design of a Creator."

Information about HB 4946 is available from the Michigan legislature's web site at <http://www.michiganlegislature.org/mileg.asp?page=getObject&objName=2003-HB-4946>.

Michigan: On July 17, 2003, House Bill 5005 was introduced in the Michigan House of Representatives by Representative Jacob W Hoogendyk Jr (R–District 61) and referred to the Education Committee. HB 5005 would amend the state school code to provide that:

> The teaching in a public school science class of the methodological naturalism hypothesis as an explanation for the origin and diversity of life shall not preclude also teaching the design hypothesis as an explanation for the origin and diversity of life. A public school official shall not censor or prohibit the teaching of the design hypothesis.
>
> As used in this section:
>
> "Design hypothesis" means the theory that life and its diversity result from a combination of chance, necessity, and design.
>
> "Methodological naturalism hypothesis" means the theory that nature is all there is and that all phenomena, including living systems, result only from chance and necessity.



HB 4705, introduced in 2001, contained the same provisions as HB 5005 and was sponsored by several of the same legislators; the 2001–2 Education Committee took no action on HB 4705 and the bill ultimately died (see *RNCSE* 2000 Sep/Oct; 20 [5]: 10 and 2001 Jan–Apr; 21 [1–2]: 7). Information about HB 5005 is available from the Michigan legislature's web site at <http://www.michiganlegislature.org/mileg.asp?page=getObject&objName=2003-HB-5005>.

Minnesota: Creationism was in the news in Minnesota even before the committee to draft the new state science standards was selected. Although Commissioner of Education Cheri Pierson Yecke said that the standards ought not to address creationism (WCCO-TV, 2003 Jun 18, <http://wcco.com/localnews/local_story_169122420.html>, she also told Minnesota Public Radio that she believes that "every local district should have the freedom to teach creationism if that is what they choose" (2003 Jun 9). In a broadcast on WCCO-TV on July 8, 2003, Yecke cited the so-called Santorum Amendment as

grounds for including "a higher power creating life alongside evolution" and said that she requested clarification from unspecified sources in Washington DC: "if they send me the exact same language that they sent to Ohio, then I feel that, you know, certainly we have the law behind us and can use that language." For information on the status of the Santorum Amendment, see *RNCSE* 2002 May/Jun; 22 (3): 4–5 or Glenn Branch and Eugenie C Scott's "The antievolution law that wasn't" (*The American Biology Teacher* 2003 Mar; 65 [3]: 165–6). Finally selected, the science standards writing committee began work on July 31; the preliminary draft was released for public comment in early September.

Missouri, Independence: A lawsuit that challenged a history teacher's religious advocacy at Truman High School was settled on June 12, 2003. The suit, brought by the American Civil Liberties Union of Kansas and Western Missouri and Americans United for Separation of Church and State on behalf of 10th-grader Ashley Heckman and her mother Evelyn Welk, charged Chris Early with engaging in religious advocacy in a variety of ways, including by assigning the late WA Criswell's sermon "The hoaxes of anthropology" as a required reading. (Criswell [1909–2002] was a pastor at Dallas's First Baptist Church, one of the largest churches in the Southern Baptist Convention, from 1944 until his retirement in 1995; among his many books is *Did Man Just Happen?* [Grand Rapids MI: Zondervan, 1957; revised edition, 1972], which Tom McIver describes in his bibliography *Anti-Evolution* as "[s]tandard creation-science arguments presented in simple, derogatory fashion.") "This sermon debunked anthropological information", Welk said. "I saw it as someone trying to impose a religious ideology. An attack on evolution should not be part of a history class." After efforts to resolve the problem with school officials failed, the suit was filed on May 1. By the terms of the settlement, Early agreed to refrain from advancing any particular religion, or religion in general, in his classroom, and the school, while denying any wrongdoing, agreed to enforce its policy of religious neutrality. (For reports by Americans United for Separation of Church and State, see *Church and State* 2003; 56 [6]: 7–8 and 2003; 56 [7]: 18–9).

Missouri, Liberty: William Jewell College, a liberal arts college founded in 1849 associated with the Missouri Baptist Convention, is expected to lose the MBC's support due to its position on a variety of issues, including the teaching of creationism. The MBC's executive board voted 44–4 to recommend that the MBC discontinue its support of the college — about $850 000 per year, roughly 3% of the college's annual budget. The recommendation is likely to be followed at the MBC's annual meeting in early November. On January 24, 2003, the Reverend Charles Burnett, chair of the MBC's executive board's interagency relations committee, sent a letter to David Sallee, the president of the college, asking for personal information about the college's faculty and trustees and for "[a] statement concerning the official teaching position of William Jewell on the first 11 chapters of Genesis, specifically the creation account"; the trustees voted on February 14 not to respond. Following the news of the MBC's executive board's vote, Judy Dilts, the head of the college's biology department, told the *Sun-News of the Northland* that creationism is not science: "We teach, because we are biologists, the theory of evolution" (2003 Jul 24; available online at <http://www.zwire.com/site/news.cfm?newsid=9887366&BRD=1452&PAG=461&dept_id=155076&rfi=6>). Although the MBC's Burnett told the *Sun-News* that the MBC's board was advocating that Genesis be taught as fact in theology classes but not in biology classes, the chair of the MBC's executive board, the Reverend Jay Scribner, was quoted as saying that creationism was appropriate for science classes as well: "Any Christian school needs to embrace and espouse the tenet of creationism."

New Mexico: At its August 27–29, 2003, meeting, the New Mexico State Board of Education unanimously voted to adopt new science standards in which evolution is central and uncompromised. Evaluating the draft standards at NCSE's request, Lawrence Lerner said, "They compare with, and in some ways surpass, the very best standards adopted to date" (*Santa Fe New Mexican* 2003 Aug 10). Of the organizations opposing evolution's place in the standards, Intelligent Design Network of New Mexico (<http://www.nmidnet.org>; see *RNCSE* 2002 Sep/Oct; 22 [5]: 14–5) is the most visible. IDNet-NM's tactics are familiar: after failing to influence the drafting of the standards, it proposed a set of standards in which evolution is systematically downplayed; it solicited New Mexican scientists — defined as possessing "advanced degrees (MS or greater) in the physical or life sciences" — to endorse a version of the Discovery Institute's "A scientific dissent from Darwinism" (see *RNCSE* 2002 Sep–Dec; 21 [5–6]: 22–3); and it commissioned Zogby International to conduct polls on "teaching scientific evidence for and against evolution" of New Mexicans in general and scientists in New Mexico in particular. The response rate for the latter poll (of staff at universities and national laboratories in New Mexico) was so low, however — 248 responses of about 16 000 surveyed — that Sandia National Laboratories president C Paul Robinson characterized the poll as "bogus" in a letter to members of the board (*Albuquerque Journal* 2003 Aug 17). Look for a detailed report on evolution education in New Mexico in a future issue of *RNCSE.*

North Carolina, Union County: Educational officials in North Carolina are in the process of revising the state's science curriculum guidelines, to be submitted to the state board of education in November 2003 and, if approved, implemented in 2004–2005. At its meeting on August 19, 2003, the Union County School Board considered a proposal to suggest that the new guidelines require the teaching of "both the strengths and weaknesses of the Theory of Evolution without religious, naturalistic, or philosophic bias or assumption" (*Charlotte Observer* 2003 Aug 21; available on-line at <http://www.charlotte.com/mld/observer/news/local/6581373.htm>). School board

member Dean Arp, who supported the proposal, explained, "The way it is now, we are teaching an evolutionary-only, naturalist-biased approach", and expressed his desire for "a balanced curriculum that's unbiased." The proposal was in effect defeated when a rival proposal for the board not to comment on the curriculum guidelines was passed. Information about the science curriculum is available on-line at <http://www.ncpublicschools.org/curriculum/science/>.

Pennsylvania, Perkasie: On March 15, 2001, Joe Baker, then a student in Pennridge High School, distributed fliers in which he alleged that there were systematic errors in the school's biology textbooks and urged students to challenge their teachers about them (*Pittsburgh Post-Gazette* 2001 Aug 26). Baker failed to submit his fliers for review in advance, which violated the district's policy; although the district allowed him to distribute them after review, he filed suit in July with the aid of the Rutherford Institute, a conservative civil-liberties group, asking for $1 in damages, attorney fees and litigation costs, and a declaration that the district's policy is unconstitutional. On March 24, 2003, a federal judge ruled that because Baker was no longer a student when he filed his suit, he lacked standing to sue except for damages; she also dismissed the administrators as defendants (*Allentown Morning Call* 2003 Apr 12). On August 5, 2003, the Pennridge School Board voted 5–1 to settle what remained of the lawsuit by agreeing to discuss revising the policy "in good faith" and to grant Baker $2 plus "reasonable" court and attorney fees; the cost of the fees would be determined by a third party (*Allentown Morning Call* 2003 Aug 5). Baker's attorneys have indicated that a settlement may not be reached if the policy is unmodified, however. Baker attained brief celebrity after a CNN report on his campaign to have the Pennridge School District add disclaimers to its biology textbooks aired in May 2001 (a transcript is available on-line at <http://fyi.cnn.com/2001/fyi/teachers.ednew05/09/evolution.debate/index.html>).

South Carolina: When the South Carolina legislature adjourned on June 5, 2003, Senate Bill 153 died. Senator Michael L Fair's amendment to SB 153, adopted by the Senate, would have established a "South Carolina Science Standards Committee"; according to the *Greenville News* (2003 May 1), Fair's "intention is to show that Intelligent Design is a viable scientific alternative that should be taught in the public schools" (see *RNCSE* 2003 Mar/Apr; 23 [2]: 12–4).

Texas: When the Texas legislature adjourned on June 2, 2003, House Bill 1447 died. HB 1447 would have returned control of textbook content to the State Board of Education, empowering it to "reject any textbook that contains factual or other errors"; in the past, opponents of evolution education have successfully worked through the board to pressure publishers to eliminate or downplay the treatment of evolution in textbooks (see *RNCSE* 2003 Mar/Apr; 23 [2]: 12–4).

Texas: On July 9, 2003, the Texas Board of Education held its first public hearing allowing the public to comment on biology textbooks proposed for adoption by the state, which is the nation's second largest textbook market. Over 200 people attended; nearly all of the three dozen speakers — including 10 members of NCSE — favored the teaching of evolution and defended the general accuracy of the textbooks against a critique of them submitted by the Discovery Institute. The critique, based largely on Jonathan Wells's *Icons of Evolution* (Washington [DC]: Regnery, 2000), graded the textbooks on their discussions of 4 "icons": the Miller-Urey experiment, the Cambrian Explosion, Haeckel's drawings of vertebrate embryos, and peppered moths. Only one textbook passed, with a grade of C–. Two fellows of the Discovery Institute testified at the hearing: Raymond Bohlin, executive director of Probe Ministries, and Francis J Beckwith, newly appointed as Associate Professor of

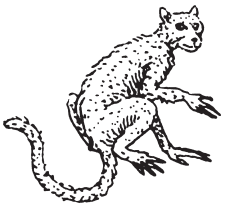
Texas Citizens for Science

Modeled on such successful groups as Kansas Citizens for Science and Ohio Citizens for Science, Texas Citizens for Science is a new grassroots organization dedicated to "maintaining the professionalism of science education in Texas public schools and the integrity of science in the Texas public school curriculum." TCS's president is Steven D Schafersman, a scientist with over two decades' experience in teaching biology, geology, paleontology, and environmental science in Texas colleges and universities. He is also a veteran of Texas's textbook adoption wars, having served as president of the Texas Committee of Correspondence.

Immediately before the Texas Board of Education's July 9, 2003, hearing on biology textbooks, TCS held a press conference at the Texas Education Agency in downtown Austin, at which Schafersman, David Hillis of the University of Texas, Austin, and NCSE's executive director Eugenie C Scott spoke and took questions from reporters. The press conference was not only well attended but well reported: Schaferman was quoted by the *Fort Worth Star-Telegram* (2003 Jul 9) as saying, "It [intelligent design] sounds plausible to people who are not scientifically informed. But they are fraudulently trying to deceive board members. They might succeed, but it will be over the public protests of scientists", and Scott was quoted by Austin's Channel 8 News as saying, "This year the approach of religious conservatives is to dumb down the coverage of evolution in the books by claiming they are full of misinformation, errors and even fraudulent coverage of science" (2003 Jul 9; available on-line at <http://www.news8austin.com/content/headlines/?ArID=77112&SecID=2>).

TCS maintains a web site at <http://www.txscience.org/> and runs an e-mail list serve that provides information about the ongoing controversy. To subscribe, send an e-mail reading "subscribe txnews <your e-mail address>" to majordomo@ncseweb2.org.

Church–State Studies at Baylor University. Bohlin told CNN, "Every theory has its weaknesses, has its problems, and evolution seems to be the one theory in the textbooks that just isn't treated that way" (2003 Jul 9; transcript available on-line at <http://www.cnn.com/TRANSCRIPTS/0307/09/se.01.html>). Speaking in defense of the textbooks, David Hillis, a biologist at the University of Texas, Austin and 8th-generation Texan, said, "I'm here to keep outside forces from removing science from science books ...The goal [of the Discovery Institute] is to insert a religious and political agenda into the science classroom" (*San Antonio Express-News* 2003 Jul 10; available on-line at <http://news.mysanantonio.com/story.cfm?xla=saen&xlb=180&xlc=1023426>). Concurring with Hillis's appraisal of the Discovery Institute's critique, Samantha Smoot, executive director of the public watchdog group Texas Freedom Network, told the *Houston Chronicle*, "There is a clear, well-coordinated effort to undermine the teaching of evolution in Texas classrooms", adding, "Intelligent design is just creationism dressed up in a laboratory coat" (2003 Jul 9; available on-line at <http://www.chron.com/cs/CDA/printstory.hts/metropolitan/1987782>). Another public hearing took place in September; the final vote on the textbooks will take place in November.



Texas, Montgomery County: A local conservative group is mounting a petition drive to mandate the teaching of "intelligent design" in all six school districts in the county. Jim Jenkins, president of the Republican Leadership Council (RLC), said that the group is attempting to convince school boards to supplement evolution with "intelligent design", reported the *Magnolia Potpourri* (2003 Jul 22; available on-line at <http://www.zwire.com/site/news.cfm?newsid=9883424&BRD=1493&PAG=461&dept_id=187627&rfi=6>). "We just want equal time", Jenkins said. "We want equal representation in the classroom." The state curriculum currently requires the teaching of evolution. Steven Schafersman, president of Texas Citizens for Science, told the *Potpourri*, "There is no scientific validity to 'intelligent design' at all", adding, "It does not belong in the science curriculum."

Germany: According to a report in *Nature* (2003 Apr 3; 422: 460), the Max Planck Institute for Plant Breeding Research in Cologne removed a piece advocating "intelligent design" from its web site, pending a decision on it by the institute's board of directors. The article, posted by Wolf-Ekkehard Lönnig, a researcher at the institute, originally appeared on the Institute's web site five years ago; in 2001, following complaints, a disclaimer identifying it as a personal opinion was added. Ulrich Kutschera, a plant physiologist at the University of Kassel, told *Nature* that "It is fine as a personal opinion expressed on a personal website, but not on the official site of a scientific organization of international status"; Kutschera was foremost in the campaign against the presence of Lönnig's article on the institute's web site. Lönnig now maintains a private web page at <http://www.weloennig.de/internetlibrary.html>. In a subsequent letter to *Nature* (2003 May 8; 423: 116), Kutschera wrote:

> In Germany, efforts to undermine evolution education mostly in the form of ID, which rejects the theory of natural selection, have evolved into a successful campaign, including a standard textbook in its fifth edition, several journals, and two professional video films in which proponents of ID such as the microbiologist Siegfried Scherer and the geneticist Wolf-Ekkehard Lönnig give interviews in the laboratories of their government-sponsored departments. The ID strategy is not to identify the "designer" as God in the Bible or for adherents to call themselves creationists; they have coined the term "theists" to describe themselves. ... Four years ago, this journal published two excellent editorials ... entitled "The difference between science and dogma" and "Combating the exploiters of creationism". I think that the time is ripe to continue this series.

Kutschera discusses creationism in Germany in chapter 10 of his book *Evolutionsbiologie: Eine allgemeine Einführung* (Berlin: Paley Buchverlag, 2001).

Hungary: According to a story in the *Budapest Sun* (2003 May 29; available on-line at <http://www.budapestsun.com/full_story.asp?ArticleId={37F83982F0614D40951FC9A296B57793}>), The King's Christian Research Institute, operated under the auspices of the Hungarian Reformed Church, is seeking accreditation from the Ministry of Education to operate as a university, under the name The King's University. Among the areas of study available at The King's University would be "creation science".

United Kingdom: The Vardy Foundation is planning to establish up to six new state-funded secondary schools in northeast England at which biblical creationism would be taught. The Vardy Foundation, headed by millionaire automobile dealer and evangelical Christian Sir Peter Vardy, runs Emmanuel College in Gateshead, Tyneside, which was in the headlines in 2002 for teaching biblical creationism alongside evolution (*The Guardian* 2002 Mar 19; available on-line at <http://education.guardian.co.uk/schools/story/0,5500,669846,00.html>). The national science standards require evolution to be taught but do not forbid the teaching of creationism in addition. At the King's Academy in Middlesbrough, scheduled to open in fall 2003, "[e]volution will be taught, other theories will be taught[,] and children will be left to take a view of it themselves", said John Burn, chief academic advisor to the Vardy Foundation (*The Guardian* 2003 Apr 29; available on-line at <http://education.guardian.co.uk/schools/story/0,5500,945524,00.html>). Richard Dawkins, the Charles Simonyi Professor of the Public Understanding of Science at Oxford University, was quoted by *The Guardian* as saying, "Evolution is supported by mountains of scientific evidence ...These children are being deliberately and wantonly misled" and as describing the curriculum as "educational debauchery".

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 — and we — have a lot to be proud about!

David L Alles and Joan Stevenson's article "Teaching evolution" appeared in *The American Biology Teacher* (2003 May; 65 [5]: 333–9). Their goals are twofold: "to show the importance of teaching human evolution to all students ... [and] to provide up-to-date resources for classroom teachers to use in teaching the subject." In the list of Recommended Web Sites was "Fossil hominids: The evidence for human evolution" (<http://www.talkorigins.org/faqs/homs/>), maintained by **Jim Foley**. Alles teaches biology and Stevenson teaches anthropology at Western Washington University. Of interest in the same issue is Paul Farber's "Teaching evolution & the nature of science" (2003 May; 65 [5]: 347–54), a thoughtful discussion of what the author calls "the standard treatment of evolution" and its flaws.

Brian J Alters, the director of the Evolution Education Research Centre at McGill University and *RNCSE*'s associate editor for education, received the Faculty of Education Award for Distinguished Teaching from McGill University at its spring convocation on June 3, 2003. With Sandra M Alters, he is author of *Defending Evolution: A Guide to the Evolution/Creation Controversy* (Sudbury [MA]: Jones & Bartlett, 2001).

NCSE Supporter **Francisco Ayala** contributed "Intelligent design: The original version" to the inaugural issue of *Theology and Science* (2003 Apr; 1 [1]: 9–32), published by the Center for Theology and the Natural Sciences. In it, he explains Paley's argument from design in detail, and then suggests that Darwin's achievement was to demonstrate that the apparent design of organisms can be explained by natural selection. Paley's argument is further weakened by his inability to provide a satisfactory account of imperfect design, Ayala argues. The article concludes with remarks on the limits of science: "science is a way of knowing, but it is not the only way." Ayala was also in the news recently: he was named as University Professor by the Regents of the University of California, a rank that only 33 other faculty members in the University of California system have ever attained. Ayala is the Donald Bren Professor of Biological Sciences in the Department of Ecology and Evolutionary Biology at the University of California, Irvine.

Philip Baringer received the Steeples Award for service to the citizens of Kansas in recognition of his work for outreach and public education, including organizing an annual "Magic Show" of physics demonstrations, which has reached thousands of school children, and leading the local implementation of QuarkNet — which includes an intensive summer experience in modern physics for regional high school physics teachers — in the high energy physics group. The award, presented annually by the College of Liberal Arts and Sciences of the University of Kansas, consists of a $1000 cash award and a $1000 yearly salary supplement. In 2001, the same award went to **Adrian Melott** for his work in the Kansas science standards controversy and his authorship of an elementary school cosmology curriculum. Like Melott, Baringer is a professor in the Department of Physics and Astronomy and a board member of Kansas Citizens for Science. [*Thanks to Liz Craig for the news.*]

NCSE Deputy Director **Glenn Branch** and Executive Director **Eugenie C Scott** collaborated on "The antievolution law that wasn't", a guest editorial for *The American Biology Teacher* (2003 March; 65 [3]: 165–6) about the so-called Santorum Amendment. "[T]he No Child Left Behind Act in no way requires teachers to teach evolution any differently", they wrote, "and teachers ought not to be intimidated by claims to the contrary." (For previous coverage of the Santorum Amendment, see *RNCSE* 2002 May/Jun; 22 [3]: 4–5.) In the same issue of *The American Biology Teacher* was a long letter from **Robert Cooper** (168–9) responding to criticism of his "Scientific knowledge of the past is possible" (*The American Biology Teacher* 2002 Aug; 64 [6]: 427–32) as well as the second half of **William F McComas**'s article "The nature of the ideal environmental science curriculum", subtitled, "Advocates, textbooks, & conclusions" (171–8; for the first half, see *The American Biology Teacher* 2002 Nov/Dec; 64 [9]: 665–72).

Paul Heinrich's article "Possible meteorite impact crater in St Helena Parish, Louisiana" appeared in *Louisiana Geological Survey News* (2003 Jun; 13 [1]: 3–5). In it, Heinrich reports on his and his colleagues' research into the Brushy Creek feature — an anomalous circular feature about 2 km in diameter in St Helena Parish — and hypothesizes that it is the result of a meteorite or comet impact. Heinrich, a life member of NCSE, is a research associate of the Louisiana Geological Survey.

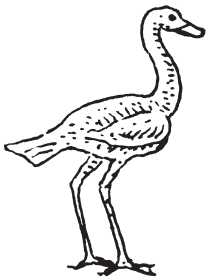
Two new books by the late NCSE Supporter **Stephen Jay Gould** are on the shelves. *The Hedgehog, the Fox, and the Magister's Pox: Ending the False War Between Science and the Humanities* (New York: Harmony Books, 2003) argues that science and the humanities are separate but equal players in the joint enterprise of wisdom. *Triumph and Tragedy in Mudville: A Lifelong Passion for Baseball* (New York: WW Norton, 2003) collects Gould's writings about America's favorite pastime, including two essays written especially for the book.

America Before the European Invasions (London: Longman, 2002), **Alice Beck Kehoe**'s account of the development of human cultures in North America north of Mexico, was favorably reviewed in *The New York Review of Books* (2003 Jun 12; 50 [10]: 51–3) by Tim Flannery, who wrote, "Its strength lies in the author's deep empathy with the people who lived their lives in vanished and barely imaginable civilizations, as well as with contemporary indigenous cultures. ... Kehoe's book does a great service to Americans."

NCSE Supporter **Philip Kitcher**, Professor of Philosophy at Columbia University, was awarded the Romanell–Phi Beta Kappa

Professorship in Philosophy for 2003–2004. Awarded annually to a philosopher in recognition of both distinguished achievement and contribution to the public understanding of philosophy, the Professorship brings with it $7500. Recipients are expected to deliver three special lectures, open to the public, at their institutions. For more details, see *The Key Reporter* 2003 Spring; 68 (3): 5.

A science teacher who was instrumental in defending the teaching of evolution in the Cobb County public schools recently was honored by the *Atlanta Journal-Constitution*. **Wes McCoy**, who teaches science at North Cobb High School in Kennesaw, Georgia, received the 2003 Honor Teacher Award, which carried with it a $10 000 grant to use for buying equipment for his classroom or otherwise benefiting his students. McCoy was profiled in the *Journal-Constitution* (2003 May 11) in a story headlined "An experimental, inspirational man". "His brand of science is not afraid to consider tough questions, including evolution, a controversial topic in Cobb County", wrote the *Journal-Constitution*'s reporter. "A devout Presbyterian, McCoy tells his students that it's possible to accept evolution and believe in God." Also, McCoy's article "Whence all the frenzy?" recently appeared in *SciTech*, the journal of the Presbyterian Association on Science, Technology, and the Christian Faith (2003 May; 12 [2]: 3, 8–9). In it, McCoy emphasized the possibility — and the desirability — of a rapprochement between Christianity and evolution.



Adrian Melott, Professor of Physics and Astronomy at the University of Kansas and a board member of Kansas Citizens for Science, received the 2003 Outstanding Educator Award from the University of Kansas's chapter of Phi Delta Kappa, the national education fraternity that provides a forum for educators to discuss research, teaching, and service in their profession.

NCSE Supporter **Kenneth R Miller** reviewed Larry A Witham's *Where Darwin Meets the Bible: Creationists and Evolutionists in America* (New York: Oxford University Press, 2002) for *Science* (2003 Jan 31; 299: 664). Praising Witham for weaving "the isolated elements of the conflict into a fabric that connects the flow of ideas, events, and politics", he nevertheless complained that "the book is at its weakest in dealing with science itself ... Witham's unfamiliarity with science is matched by a surprising willingness to accept claims that evolutionary biology is primarily an ideological movement." Miller is Professor of Biology at Brown University.

Randy Moore and his colleagues Murray Jensen and Jay Hatch were the focus of "GC biology curriculum focus on evolution", a story in *Access*, the General College Newsletter of the University of Minnesota (2002 Winter; 1 [2]: 8–9; available on-line at <http://www.gen.umn.edu/news/images/access_2002_winter.pdf>). Moore was described as "one of the nation's leading experts on the evolution–creationism controversy, having published numerous articles and a new book [*Evolution in the Courtroom* (Santa Barbara [CA]: ABC-Clio, 2001)] on the subject." Moore, Jensen, and Hatch recently collaborated on "Twenty questions: What have the courts said about the teaching of evolution and creationism in public schools?" (*BioScience* 2003 Aug; 53 [8]: 766–71), which provides answers to the most common questions about the legal issues associated with evolution education. Moore is Professor of Biology at the University of Minnesota and editor of *The American Biology Teacher*.

M Patricia Morse is the 2003 recipient of the Education Award from the American Institute of Biological Sciences, which brings with it a plaque and a lifetime membership in AIBS. The award is presented annually to individuals and groups who have made significant contributions to education in the biological sciences; previous recipients are the late **John A Moore** (in 2002) and **Rodger Bybee** (in 2001). In her acceptance speech, Morse stressed the importance to biology education of a sense of wonder: "Biology offers an amazing way of knowing about the wonders of the natural world, and every student deserves the opportunity to experience the nature of discovery" (see *BioScience* 2003 May; 53 [5]: 529–32 for a complete report on AIBS's 2003 awards). Morse, a marine biologist and science educator at the University of Washington, is a life member of NCSE.

Bryan Myres wrote to *New Scientist* to criticize the misuse of the word "theory" in a previous article. "Creationists and others who are antiscience focus on 'theories', assuming that this term means they are mere guesses", he remarked. "I cannot imagine what has happened to the word 'hypothesis' and why science writers never seem to use it. In mixing these words, they do a grave injustice to science, and provide ammunition to science's enemies." His letter was printed under the title "Theories aren't guesses" (*New Scientist* 2003 Apr 19; available online at <http://www.newscientist.com/opinion/opletters.jsp?id=ns23917>). Myres was pleasantly surprised to receive a note from the offending author, who agreed that his use of the word "theory" was sloppy.

Margaret "Betsey" Ott, Instructor of Biology at Tyler Junior College in Tyler, Texas, has been elected President-Elect of the National Association of Biology Teachers. Betsey will assume the presidency in 2004. She is a longtime NCSE member and supporter of evolution education. Other NCSE members who have served as president of NABT include **Betty Carvellas**, **Joe McInerney**, and **Brad Williamson**.

NCSE President **Kevin Padian**'s viewpoint article "Four-winged dinosaurs, bird precursors, or neither?" appeared in *BioScience* (2003 May; 53 [5]: 450–2). In it, Padian comments on the latest find of fossils of *Microraptor gui* as reported by Xu Xing and his colleagues ("Four-winged dinosaurs from China", *Nature* 2003; 421: 335–40), referring to it as "an incredible discovery, the kind of thing that we've wished for — well, for centuries now." He took issue with some of the inferences of their article, suggesting that extensive review and discussion will be needed to resolve the issues, but concluded that "this is an extraordinary find, and these specimens provide a lot of intriguing information about how much equipment for flight was present in the small theropods that were closest to birds."

Publications by **Steve Reuland**, a graduate student in the Department of Biochemistry and Molecular Biology at the Medical University of South Carolina, recently appeared in two quite different venues: the *Journal of Biological Chemistry*

(Reuland SN, Vlasov AP, and Krupenko SA, "Disruption of a calmodulin central helix-like region of 10-formyltetrahydrofolate dehydrogenase impairs its dehydrogenase activity by uncoupling the functional domains", 2003 Jun 20; 278 [25]: 22894–900) and *Salon* (<http://www.salon.com/tech/letters/2003/08/22/creation_science/index.html>).Writing to applaud Katharine Mieszkowski's article on the textbook furor in Texas (*Salon* 2003 Aug; <http://www.salon.com/tech/feature/2003/08/20/textbook/index_np.html>), Reuland explained, "It is clear that the [intelligent design] movement's motives are entirely political and religious in nature, and are part of a broader strategy in the extreme right's 'culture war.' They have no real interest in science. To achieve their ends, they employ the worst tactics of ideological demagoguery."

The Delta chapter of the biological honor society Beta Beta Beta, at Southwestern College in Winfield, Kansas, received the Lloyd M Berthold Chapter Award for its outstanding academic achievements and activities during the 2001–2002 school year. The award is conferred annually to the chapter that has best promoted the triple aims of Beta Beta Beta: scholarship, dissemination of scientific information, and promotion of biological research. The chapter's advisor is **Pat Ross**, Associate Professor of Biology at Southwestern. [*Thanks to Liz Craig for the news.*]

NCSE Supporter **Michael Ruse**, the Lucyle T Werkmeister Professor of Philosophy at Florida State University, received an honorary DLitt degree from McMaster University in Hamilton, Ontario, at its convocation on June 3. Ruse earned his MA in philosophy from McMaster in 1964, before going on to earn his PhD from the University of Bristol. His latest book is *Darwin and Design* (Cambridge: Harvard University Press, 2003).

On June 3, 2003, NCSE executive director **Eugenie C Scott** received an honorary Doctor of Science degree from one of Canada's premier institutions of higher learning, McGill University, in Montreal, Canada. McGill's guidelines for the awarding of honorary degrees explain that "By awarding honorary degrees, the University recognizes those individuals whose accomplishments are of such excellence that they provide inspiration and leadership to its graduates. As well, through its choice of honorary degree recipients, the University makes a public declaration of its values. In selecting candidates, the University should attempt to choose individuals of such a calibre that in honoring them, it too is honored." The Principal and Vice-Chancellor of McGill, Bernard J Shapiro, wrote to Scott, "It is the opinion of both our Honorary Degrees and Convocations Committee and the University Senate that over the course of your career you have more than met these criteria."

Victor J Stenger's latest book *Has Science Found God? The Latest Results in the Search for Purpose in the Universe* (Amherst [NY]: Prometheus, 2003) is on the shelves. Stenger, emeritus Professor of Physics and Astronomy at the University of Hawai'i, critically reviews contemporary attempts to resurrect natural theology, including creationism. *Has Science Found God?* was the Editor's Choice in *Research News and Opportunities in Science and Theology* (2003 Jun; 3 [10]: 21; available on-line at <http://www.researchnews.org/june03/bookends_ed_choice.html>); Karl Giberson described it as a "polemical, no-holds-barred, personal, often idiosyncratic survey" and "a fresh look at the 'evidence' for God from someone who does not believe."

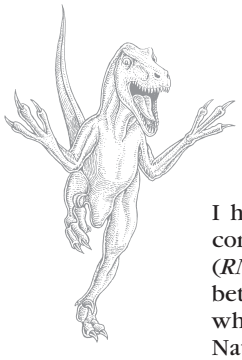
Mark Terry, chair of the science department at the Northwest School in Seattle, collaborated with Scott Linneman, Assistant Professor of Geology and Science Education at Western Washington University, on "Watching the wedge: How the Discovery Institute wishes to change the teaching of science" for the *Washington State Science Teachers' Association Journal* (2003; 43 [1]: 12–5).With especial reference to the controversy over the Ohio state science standards, Terry and Linneman described the strategy of the Discovery Institute's Center for Science and Culture in detail:

1. Place ID advocates on writing committees, boards of education, and state education committees.
2. Go public, with lots of press interviews, talk shows, speeches, video, debates.
3. Make the inclusion of ID in science classes seem like a free-speech issue.
4. Make scientists sound like the dogmatic ones.
5. Make all references to ID in language that sounds scientific, not religious.
6. Try to broaden the definition of science teaching and even science itself, to eliminate the restriction to natural causes and require reference to a Designer.
7. Settle for various levels, claiming any and all as victories: any public debate is a victory; any press coverage is a victory; any waffling in the standards is a victory.
8. Claim victory in the press.
9. Be patient, look for the next opportunity, and learn everything possible from the battle in each state.

Margaret Towne taught a weeklong course from June 2 to June 8, 2003, at Ghost Ranch, an education and retreat center of the Presbyterian Church (USA) in Abiquiu, New Mexico. Entitled "Genesis and Evolution: Integration", her course was designed for high school and college students, but was also intended to be suitable for others — seminarians, parents, public school teachers, college and seminary faculty, school board members, pastors, youth workers — interested in the creationism/evolution controversy.Towne teaches in both the philosophy and the biology departments at the University of Nevada, Las Vegas; she is also coeditor of the *Newsletter of the American Scientific Affiliation & Canadian Scientific & Christian Affiliation*.

Responding to a letter to the editor of the *Topeka Capital-Journal* that claimed that there are well-qualified creation scientists who have demonstrated the fallacies of evolutionary theory (2003 May 26), **Thair Witmer** asked, "if there were indeed so much doubt within academia about the validity of the theory of evolution, why is there an overwhelming consensus in the scientific community, which accepts it as the best explanation for the origin of species?" He answered his own question by explaining that "[t]he evidence in favor of evolution speaks loud and clear". Witmer's letter appeared on June 2.

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



Letters to the Editor

I have just been reading with some considerable interest the interview (*RNCSE* 2002 Nov/Dec; 22 [6]: 27–30) between Glenn Branch and the somewhat smug Frederick Crews. Naturally, a topic discussed was Crews's article in the *New York Review of Books*, where he criticized not just the creationists but also those who would reconcile Darwinism with Christianity, including the late Stephen Jay Gould, the theologian John Haught, and me ("Saving Us from Darwin", *New York Review of Books* 2001 Oct 4; 48 [15]: 24–7 and Oct 18; 48 [16]: 51–5). Crews felt that my book *Can a Darwinian be a Christian? The Relationship between Science and Religion* (Cambridge: Cambridge University Press, 2000), where I argue for an affirmative answer to the question I posed in my title, failed badly in its attempt, and in the interview he drew attention to a like-minded review of the book by the Chicago geneticist Jerry Coyne ("Intergalactic Jesus", *London Review of Books* 2002 May 9; 24 [9]).

I have responded already to Crews's charge, arguing that he is ignorant of Christian theology and should not pontificate on these matters until he is prepared to do some homework. Since, in the interview, he admits openly that "I would never read theological tracts for pleasure, improvement, or uplift", there is obviously little point in saying more in this respect. But there is an issue that should be addressed, despite Crews's concern that I take umbrage simply because I feel that "a pro-Darwinian reviewer should have given his book a free pass for political reasons." For the record, let me assure him that not only do I have the kind of personality that enjoys a good fight, but also I have always been open in saying that we Darwinians must always be free to disagree publicly. That is what distinguishes from our opponents — our realization that we must be self-critical. No idea is sacred. Eugenie Scott has suffered mightily from my loud mouth in this respect, fearing my lack of tact far more than Phillip Johnson's lawyer's wiles.

My concern is that if Darwinism implies atheism (or even just the falsity of Christianity) — which seems to be the position of Crews and Coyne and is certainly the position of Richard Dawkins, Daniel Dennett, and David Hull (to name 3 others who have written on these matters) — then, given the United States' constitutional separation of church and state, I simply do not see how one can legitimately teach Darwinism in state-supported schools in this country. I am not saying one should not be a Darwinian, I am not saying one should not be an atheist — I myself am a Darwinian and, if not an atheist, very skeptical about religious claims — but I am saying that if one links the two, seeing the latter as a consequence of the former, then our creationist opponents are absolutely right in saying that, inasmuch as we teach Darwinism, we are teaching a religious position. At the least, if one thinks that no breach of the science/religion wall is occurring, then it behooves us to show us why we are allowed to do it, and not creationists when they want to teach "intelligent design".

As it happens, I agree with Gould and Haught (although for different reasons) that one can be a Darwinian and a Christian (or a skeptic or an atheist), so I can teach Darwinism with a clear conscience. But let me assure you that I reached this conclusion from the arguments I presented in *Can a Darwinian be a Christian?* So your readers may feel assured that, although I may be a fool to think my arguments convincing, I am not a hypocrite. I am not advancing arguments I think false, for political ends.

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As a long-time member of NCSE, and as a card-carrying evolutionist, I must say that I am in full agreement with Frederick Crews (*RNCSE* 2002 Nov/Dec; 22 [6]: 27–30) regarding the apparent positions of some of us who try too hard to be agreeable with religion, not to offend, and, perhaps, to be "politically correct": Darwin's theory is a materialist explanation.

Evolution rides on its own wheels — mechanistic processes defined and explicated through the scientific method.

We should never have agreed to pulling the words from a definition of evolution that make explicit that this biological core is, indeed, a materialist explanation. NABT teachers must stand firm on this. Pulling them out makes it appear that we are pulling a Chamberlain in appeasing the ignorance of the "religious" right. In my experience, they seize upon appeasements as weaknesses and attack with even more vigor. It makes our position appear weak and wishy-washy, and leaves us vulnerable to being hoisted by our own petards.

I do not teach evolution in my classes to make some people feel good by opening doors of rapprochement. It is said that the supernatural belongs in church — believe what you will, but evolution is *not* a system of beliefs. Rather, it is a mechanistic explanation of the diversity of life on earth, and one day, soon, an explanation of how chemical evolution produced life itself. There is no church here, no *élan vital*, only science continuing to chip away at ignorance and thus giving us enlightenment about the mysteries (all potentially soluble) of our universe and life.

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Author's Query:
Why Natural Selection?

I am writing a paper on the reasons that biologists during the period 1920–1970 accepted (or rejected) natural selection as the primary cause of evolution. (This is part of a comparative study of the reasons why scientists in different disciplines — from physics to sociology — accept or reject new theories and discoveries. A paper on the reception of TH Morgan's chromosome theory of heredity has recently been accepted for publication in the *Journal of the History of Biology*.) I would like to hear from biologists and biology teachers, especially those who were educated before 1970, about the reasons that they came to believe (or not believe) that natural selection is the primary cause of evolution. Recollections about books, articles, teachers and colleagues who were influential in this respect would be welcome. (Do you remember a particular textbook?)

Please send your replies and inquiries directly to:

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The Astrobiological Perspective on Life's Origin

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Astrobiology is a new term for the study of the origin, evolution, distribution, and destiny of life in the universe. It uses multiple scientific disciplines and space technologies to address some of the most profound questions of humankind: How did life begin? Are there other planets like earth? What is our future as terrestrial life expands beyond the home planet? For the first time in human history, advances in the biological sciences, informatics, and space technology make it possible for us to provide some answers.

In this paper, I discuss contributions that the new field of astrobiology can make to questions of life's origins. I am an astronomer and space scientist, not a biologist or biochemist. My perspective is therefore that of an interested outsider. But as an astrobiologist, I look at the state of knowledge in the field and try to make some judgment about directions in which current research seems to be taking us.

The paper has 3 parts. First is a discussion of the nature of astrobiology, using the NASA Astrobiology Roadmap as a way of organizing the subject. Second is a review of the conditions on earth when life began. Third is a perspective on current origins research.

The nature of astrobiology

The United States National Aeronautics and Space Administration (NASA) has encouraged the new discipline of astrobiology by organizing workshops and technical meetings, establishing a NASA Astrobiology Institute, providing research funds to individual investigators, ensuring that astrobiology goals are incorporated in NASA flight missions, and initiating a program of public outreach and education. NASA's role comes from its history of studying the origin of life and searching for evidence of life on Mars and elsewhere in our solar system. These studies have traditionally been called "exobiology". Under the broader umbrella of astrobiology, however, research has expanded to include the search for life within other planetary systems, as well as investigation of the response of terrestrial life to global changes on the earth and to exposure to conditions in space and on other worlds. Astrobiology addresses not only our origins, but also our aspirations to become a space-faring civilization.

One description of astrobiology is provided by the NASA Astrobiology Roadmap (available at <http://astrobiology.arc.nasa.gov/roadmap/>). This Roadmap, completed in 1999, defines the content of astrobiology as perceived by scientists at its birth. It is a starting point only, and astrobiology is maturing as new information is obtained and diverse scientists bring their own perspectives to this discipline.

Astrobiology addresses 3 basic questions, which have been asked in some form for generations.

- How does life begin and evolve? (Where did we come from?)
- Does life exists elsewhere in the universe? (Are we alone?)
- What is life's future on earth and beyond? (Where are we going in space?)

These very general questions are then explored by means of 10 scientific goals:

1. Understand how life arose on the earth.

Terrestrial life is the only form of life that we know, and it appears to have arisen from a common ancestor. How and where did this remarkable event occur? We can now perform historical, observational, and experimental investigations to understand the origin of life on our planet. We should determine the source of the raw materials of life, either produced on this planet or arriving from space. We should seek to understand in what environments the components may have assembled and what forces led to the development of systems capable of deriving energy from their surroundings and manufacturing copies of themselves.

2. Determine the general principles governing the organization of matter into living systems.

To understand the full potential of life in the universe, we must establish the general physical and chemical principles that lead to the emergence of systems capable of

energy extraction and growth (catalysis and metabolism), generating offspring (reproduction), and changing as conditions warrant (evolution). Must all life be based on something similar to terrestrial biochemistry and molecular biology? How can laboratory experiments and computational simulations help us to understand life as a more general phenomenon?

3. Explore how life evolves on the molecular, organism, and ecosystem levels.

Life is a dynamic process of changes in energy and composition that occurs at all levels of assemblage, from the molecular level to ecosystem interactions. Much of traditional research on evolution has focused on organisms and their lineages as preserved in the fossil record. However, processes such as the exchange of genetic information between organisms and changes within DNA and RNA are key drivers of evolutionary innovation. Modern genetic analysis, using novel laboratory and computational methods, allows new insights into the diversity of life and evolution at all levels.

Astrobiology addresses not only our origins, but also our aspirations ...

4. Determine how the terrestrial biosphere has co-evolved with the earth.

Just as life evolves in response to changing environments, changing ecosystems alter the environment of earth. Scientists can trace the co-evolution of life and the planet by integrating evidence acquired from studies of current and historical molecular biology (genomics) with studies of present and historical environments and organismal biology. We seek to understand the diversity and distribution of our ancient ancestors, to identify specific chemical interactions between the living components of the earth (its biosphere) and other planetary subsystems, and to trace the history of earth's changing environment in response to external driving forces.

5. Establish limits for life in environments that provide analogs for conditions on other worlds.

Life is found on the earth anywhere liquid water is present, including such extreme environments as the interior of nuclear reactors, ice-covered Antarctic lakes, suboceanic hydrothermal vents, and deep subsurface rocks. To understand the possible environments for life on other worlds, we must investigate the full range of habitable environments on our own planet, both today and in the past.

6. Determine what makes a planet habitable and how common such worlds are in the universe.

Where should we look for extraterrestrial life? Based on our only example (life on earth), liquid water is a requirement. We must therefore determine what sort of planets are likely to have liquid water and how common they might be. Studying the processes of planet formation and surveying a representative sample of planetary systems will determine what planets are present and how they are distributed, essential knowledge for judging the frequency of habitable planets.

7. Determine how to recognize the signature of life on other worlds.

We are poised on the brink of searching for life, past or present, on a variety of worlds. This search requires that we be able to recognize extraterrestrial biospheres and to detect the signatures of extraterrestrial life. We must learn to recognize structural fossils or chemical traces of extinct life that may be found in extraterrestrial rocks or other samples. And we must develop a catalog of possible signatures of life that can be identified astronomically in planets circling other stars.

8. Determine whether there is (or once was) life elsewhere in our solar system, particularly on Mars and Europa.

Exciting data have presented us with the possibility that at least two other worlds in our solar system have (or have had) liquid water present: Mars and Europa. Extensive exploration of the Martian surface will be required to evaluate the total potential for life on that planet, both past and present. Furthermore, exploration of the subsurface probably offers the only credible opportunity to find extant life on either Mars or Europa.

9. Determine how ecosystems respond to environmental change on time scales relevant to human life on earth.

Research at the level of the whole biosphere is needed to examine the habitability of our planet over time in the face of both natural and human-induced environmental changes. To help to ensure the continuing health of this planet and to understand the potential long-term habitability of other planets, we need predictive models of environment–ecosystem interaction.

10. Understand the response of terrestrial life to conditions in space or on other planets.

What happens when terrestrial life is moved off its home planet and into space or to the moon or Mars, where the environment is very different from that of earth? Can organisms and ecosystems adapt to a completely novel environment and live successfully over multiple generations? Are alternative strategies practical, such as bioengineering organisms for specific environments? The results from attempting to answer such questions will determine whether earth's life can expand its evolutionary trajectory beyond its place of origin.

Although it is defined in terms of a research agenda, astrobiology also lends itself to education and outreach. The three theme questions strike a chord of interest among both students and the public. Courses built around these questions offer a powerful platform to discuss issues such as deep time, astronomical and biological evolution, and our place in the universe. On a slightly more sophisticated level, this multidisciplinary field illustrates different styles of approaching science such as con-

trasting the historical versus experimental research and exploratory versus hypothesis-driven research. A new NSF-supported upper-school curriculum, "Voyages Through Time", provides a highly appealing introduction to evolution on multiple levels: evolution of the universe, planets, life, and intelligence. At the college level, many astronomers (in particular) have begun to offer general-education courses on "astrobiology" or "life in the universe". Two new college-level textbooks have been published, and the popularity of such courses is rapidly growing.

The origin of life on earth: Context

The first goal of astrobiology discussed above is to understand the origin of life on earth. Such a study requires that we look at the astronomical and planetary evidence concerning the early environment of earth, as well as the likely chemical pathways that led to life. This study overlaps with the two goals that deal with the general conditions for the origin of life in the universe and with understanding the evolution of life on earth, especially in the microbial world.

Let us be clear at the beginning that we do not understand the origin of life on earth in any detail. Indeed, we are not even sure that life began here. There are some arguments that Mars might have been a more suitable environment for the origin of life 4 billion years ago. Since Mars and Earth have exchanged materials throughout their history, it is possible that life has migrated from one planet to another. This modern form of panspermia has its advocates, but the simplest hypothesis is that life formed on earth. If it began on Mars instead, the processes are probably similar to those that we hypothesize for our own planet.

The solar system formed 4.5 billion years ago from a collapsing cloud of gas and dust that already contained a rich complement of organic material. Astronomical investigations of similar "molecular clouds" that exist today have revealed more than 120 molecules, including such complex substances as ethyl alcohol. The so-called biogenic elements (oxygen, carbon, nitrogen, sulfur, and phosphorus) are among the most common interstellar constituents, once we get beyond hydrogen and helium, which make up 99% of the visible universe. Given the abundance of hydrogen and oxygen, water is one of the main molecules. The simple building blocks for life were thus readily available even before the formation of the planets.

The planets themselves condensed from a disk of gas and dust spinning around the protosun. Some of the pre-existing organic chemicals probably survived this formation process, but most may have been destroyed and then reconstituted within the cooling disk, and perhaps destroyed a second time as the planets coalesced. We know from the study of the oldest meteorites that organics were abundant in the disk; the common carbonaceous meteorites are composed of a few percent carbon by weight, partly elemental and partly in the form of organic compounds. One of these, the Murchison meteorite, yielded 74 separate amino acids. Most of these included equal amounts of right- and left-handed molecules, indicating their non-biological origin. The earth and other rocky planets accreted a veneer of volatiles (including water) and organics from the rain of comets and meteorites that continued for the first half-billion years after the surface cooled. These external sources may have been a more important source of organics than Miller-Urey–type synthesis in the atmosphere and ocean, especially as the initial atmosphere of earth is now thought to have consisted largely of carbon dioxide and been neither strongly reducing nor strongly oxidizing.

What were conditions like on the early earth? Since no rocks have survived from that era, we do not know for sure, but some generalizations seem robust. Although initially hot, the surface layers cooled quickly, and oceans formed. The hot interior undoubtedly contributed to a high rate of volcanism, but surface conditions were then, as now, dominated by solar heating, not volcanism. From their study of stellar evolution, astronomers are confident that the early sun was about 35% less luminous than today (a condition called the "faint young sun paradox" by those who note the contradictory evidence for a relatively constant surface temperature over the history of the earth). Therefore either the earth had a large atmospheric greenhouse effect to maintain surface temperatures above freezing or else the primitive oceans froze. We can imagine an initial carbon dioxide greenhouse effect that partly compensated for the faintness of the sun but left frozen oceans like the Arctic Ocean today. The marine environment thus paradoxically included both a relatively cold surface and an abundance of volcanically-driven hydrothermal systems in the depths. However, there probably were not any of Darwin's "warm little ponds" on the surface, and the surface might have been bathed in ultraviolet light, depending on the mass and composition of the early atmosphere.

Other external agents in addition to the faint sun influenced the environment of the early earth. The lunar cratering history, among several lines of evidence, shows that the rate of asteroid and comet impacts on the earth was much higher before 3.9 billion years ago. Although it is unclear whether there was a short-lived burst of impacts (a "late heavy bombardment") or a steadily declining impact rate dating all the way back to the accretionary period, the impacts were sufficient to influence the surface environment. Then as now, the greatest effects are from the rarest, largest impacts, happening at intervals of millions of years. It is likely that the earth was struck several times with sufficient energy to boil away most or all of the oceans. Although the surface would cool and the oceans recondense within a few thousand years of such an impact, the effects on any nascent life would have been catastrophic. This bombardment by a few projectiles hundreds of kilometers in diameter has been termed the "impact

Let us be clear at the beginning that we do not understand the origin of life on earth in any detail.

frustration" of the formation of life. It suggests that life might have formed several times and then been wiped out in such a sterilizing catastrophe. It also suggests the presence of one or more thermal bottlenecks in the early evolution of life, a topic I will return to below.

The origin of life on earth: Evidence

There is very little surviving geological evidence from the first 500 million years. What we know of impact history, for example, is derived from studies of the moon, not directly of the earth itself. The earliest fossils date from sometime after the end of the heavy bombardment.

Study of the early geological record of life dates back half a century, when Stanley Tyler, Elso Barghoorn, and William Schopf identified fossil microbes in the 2.1 billion–year-old Gunflint chert. By 1993, Schopf had found what appeared to be the oldest fossils in the Apex chert of Western Australia at 3.46 billion years. Schopf also suggested on the basis of morphological evidence that these fossil microbes were probably photosynthetic cyanobacteria. However, this work has recently come under attack, and at this writing the situation remains unresolved. In particular, the crucial conclusion that photosynthesis was operative on earth 3.5 billion years ago is in dispute. In any case, there seems to be no question that microbial fossils can be dated to at least 3.0 billion years. Macroscopic fossils in the form of stromatolites — layered constructs built up by generations of microbial mats — have also been found with similar ages.

The last common ancestor is likely to have been the survivor of a "bottleneck" resulting from a catastrophe that wiped out its predecessors.

A complementary approach is to look for an isotopic signature that indicates the presence of life in sufficient quantities to influence the global chemistry of the planet, even if individual fossils have not survived. Stephen Mojzsis and others argue on this basis for the presence of diverse bacteria on earth before 3.85 billion years. If these interpretations are correct, the interval between the end of the late heavy bombardment and the development of a robust global biota is remarkably short.

The major alternative way to study early life is to examine genomic evidence. Similarities and differences in DNA and RNA sequences illustrate relationships related to their lineage. In the case of the metazoans whose fossil remains dominate natural history collections, genomic analysis is a powerful supplement to more traditional studies of evolution. In the microbial world, such studies provide us with almost our only access to the lineages of life. Given that life on earth was exclusively microbial for the first 85% of its history, and that microbes still dominate in terms of biomass and range of habitats, these tools are invaluable for the astrobiologist. Much of astrobiology research is focused on the smallest but most numerous of life's creatures.

Carl Woese pioneered the comparison of 16s mitochondrial RNA, a highly conserved sequence that can be found in almost every living thing. By the late 1980s, he had established the division of life into 3 domains, Bacteria, Archaea, and Eukarya. The molecular phylogenetic "tree of life" based on mitochondrial RNA provides us with an entirely new way to look at the diversity of earth's biota. This diversity, and by implication its evolutionary history, is dominated by microbes within all three domains; the metazoans that have evolved since the Cambrian explosion are banished to a few outlying twigs. Although we do not know the rate of change for mitochondrial RNA in any absolute sense, the conclusion is clear that natural selection has been at work throughout the development and diversification of the microbial world. Today's microbes should not be called primitive; they are in fact highly versatile creatures that occupy a much greater range of ecological niches than do the more familiar Cambrian metazoans.

Molecular phylogeny is based on the relationships among extant biota. It cannot be used to analyze the mineralized fossils that make up most of the historical record of life on earth — we cannot, for example, use gene mapping to compare an *Eohippus* with a modern horse, as we can a human and a chimpanzee. Still less are we able to determine the genomic content of ancient microbes, which must have been quite different from anything that survives today. But it is possible to determine which extant microbes are probably similar to the inferred precursors of modern life. This is sometimes ambiguous, especially when we consider that there has been a history of gene transfers among different lineages that can shuffle the deck in ways that make reconstruction nearly impossible. With these caveats, however, a number of suggestions have been made that the most "primitive" organisms today are anaerobic thermophiles — that is, microbes that are happy in oxygen-free environments at high temperatures. Many are also methanogens, microbes that generate methane. These studies suggest, even if they do not prove, that our earliest common ancestors had similar properties.

Even if the common ancestor or ancestors of today's life were high-temperature, methane-producing microbes, this does not mean that these are representative of the first life. Almost certainly there were many precursors that existed and evolved before the invention of DNA. In addition, however, the last common ancestor is likely to have been the survivor of a "bottleneck" resulting from a catastrophe that wiped out its predecessors. One such possibility is the largest impacts of the heavy bombardment. If the surface and upper layers of ocean were sterilized by an impact, the most likely survivors would be thermophiles from the ocean depths, and it is these survivors who could have repopulated the planet.

The origin of life on earth: Theory

Putting the pieces together to form the first life is a daunting problem. Many scientists who look at the great progress that has been

made in understanding the chemical steps along the road toward life are justifiably pleased and optimistic. Others look at the huge gaps that remain and are more cautious. The following is the briefest overview of many complex issues. In preparing this summary, I have been influenced by Belgian Nobel laureate Christian de Duve (*Vital Dust: Life as a Cosmic Imperative* [New York: Basic Books, 1995]; *Life Evolving: Molecules, Mind and Meaning* [New York: Oxford University Press, 2002]) and by Australian physicist Paul Davies (*The Fifth Miracle: The Search for the Origin and Meaning of Life* [New York: Simon & Schuster, 1999]).

The earliest life needed to acquire several basic capabilities. These include assembly of the necessary raw materials within a structure, metabolism (extracting useable chemical energy from the environment), and reproduction, which ultimately involved information-storing molecules such as RNA and DNA that were themselves capable of replication. Each of these is a challenge, and they can hardly have appeared simultaneously.

The first step was surely the chemical factory that extracts energy and uses it to assemble complex molecules. Many such chemical reactions were possible, especially in a rich organic "soup" of amino acids and other organic chemicals. The key was to be able to select and control the rate of these reactions using the biological catalysts called enzymes. The energy sources could have included the conversion of sugars to alcohol or lactic acid by fermentation, or the formation of methane from carbon dioxide and hydrogen by oxidation, depending on available raw materials.

As chemical synthesis became more important, it was necessary to segregate different materials physically. Such segregation can be accomplished by membranes composed in part of lipids, which react with water to form nearly impenetrable barriers. A number of recent experiments and computer simulations have studied simple membranes and the ways they can incorporate proteins to permit partial permeability. A successful cell (or protocell) must eventually develop the ability to admit food and expel waste. Such simple membranes can readily form closed quasi-spherical chambers. In one interesting experiment, organic materials extracted from a meteorite spontaneously formed such closed systems when exposed to water.

Today, DNA is life's primary information storage and retrieval system, but we also use a simpler system based on RNA, which has the property of participating in protein synthesis as well as storing information. Most workers now think that an RNA world must have preceded the development of DNA. Gerald Joyce of the University of California, San Diego, among others, has carried out extensive experimental studies of the RNA world, demonstrating the ability of RNA to evolve in the test tube. DNA could later have been developed as a more stable information storage system by something akin to the reverse transcription process that can still be observed today.

What processes brought these components together? De Duve makes the case that it cannot have been chance — the probabilities are far too small for self-assemblage of even the simplest such systems in the lifetime of the universe. To paraphrase de Duve, the process must have involved many chemical steps that had a high probability of taking place under prevailing conditions. This progression must have led from prebiotic organic chemistry to biochemistry, and selection effects must have been important in favoring certain chemical pathways. If this is correct, the process could have been rapid, and life should have been able to start in the few million years of stable conditions that separated major impact catastrophes.

The product of this sequence of events — the first protocells — may have been quite different from life that survives on earth today. Even the oldest common ancestor of today's life probably represents a much more sophisticated system than the first recognizable life. But once natural selection came into play, the means existed for life to evolve. The key challenge, it seems to me, is to understand the selection processes that acted before the formation of the first protocell. It is these processes that must have guided the complex sequence of chemical changes that gave birth to life on the early earth, and, if life exists there, in the rest of the universe, too.

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NASA Selects New Astrobiology Institute Teams

On June 24, 2003, the National Aeronautics and Space Administration (NASA) announced an expansion of its Astrobiology Institute (NAI) — an international research consortium. NAI will add 12 new research teams to its program to study the "origin, evolution, distribution and future of life on earth and in the universe." The new teams represent a broad array of research specialties and will embody a collaborative and interdisciplinary approach to the program. For more information about NAI, visit <http://nai.arc.nasa.gov/>. News releases about this program and other NASA astrobiology projects can be found at <http://amesnews.arc.nasa.gov>.

[*Thanks to Gary Bennett for alerting NCSE to this announcement.*]

Self-Assembly of Organic Molecules and the

by David W Deamer

Movies are the myths of late–20th-century western culture. Because of the power of films like *ET* to capture our imagination, we are more likely than past generations to accept the possibility that life exists elsewhere in our galaxy. Such a myth can be used to sketch the main themes of this article, which concern the origin of life on earth.

Imagine that 4 billion years ago, intelligent beings evolved on an earth-like planet in the solar system of a neighboring star. After 10 million years of evolution, they have solved the problems of interstellar travel and aging. Virtually immortal family groups set out to explore the galaxy and almost immediately discover a solar system associated with a nearby star only 80 light years away from their home planet. They find that the third planet is rich in the primary elements of life — carbon, hydrogen, oxygen and nitrogen — which are present in the atmosphere in the form of carbon dioxide (CO_2), molecular nitrogen (N_2), and water vapor (H_2O). They decide to spend a few centuries studying this planet, which they consider to be a possible model of their own primordial world as it was 4 billion years in their past.

They learn that the planet gained most of its mass through a process called accretion, in which gravitational attraction causes dust particles to gather first into small asteroid-sized planetesimals, which then undergo immensely energetic collisions to form ever-larger planetary bodies. A single moon looms in the sky, the result of one such collision during the final stages of accretion. The planet and its moon were molten after the collision, reaching temperatures of volcanic lava that degraded all organic compounds, leaving only their elements in the form of volatile gases. Additional carbon dioxide and water vapor continued to pour into the atmosphere through immense volcanoes that allowed outgassing from the planet's interior. The planetary and lunar crusts soon cooled by radiating heat into outer space, so that the moon's hardened surface began to preserve the accumulating record of impacts over the several hundred million years that followed the moon-forming collision event.

Now the global temperature has fallen to the point that water has condensed into vast, shallow oceans that virtually cover the planetary surface, with lava and pumice islands rising from undersea volcanic regions. Because of the very high atmospheric pressure of carbon dioxide, the temperature of the oceans is still well above the boiling point of water on the visitors' home planet. The planet is devoid of life, sterilized by the immense energies released by the original collision and later giant impacts. But the impacts have largely ceased, and the temperature continues to drop to the point at which organic carbon compounds remain stable for days, years, then decades. Some of these compounds are continuously synthesized at the planet's surface by a variety of chemical reactions, often using light as an energy source, while others are delivered by the infall of microscopic dust particles, which is still adding the last few kilometers to the planet's diameter. As a result, organic substances begin to accumulate in the shallow seas, then become more concentrated by evaporation of tide pools and adsorption to mineral surfaces in submarine geothermal regions. The visitors take samples of the foamy material in the tide pools and examine it with their powerful microscopes. There is nothing alive, but they are surprised to find that some of the organic compounds have spontaneously aggregated into a variety of structures, including microscopic bubbles and molecules made up of long chains of amino acids. What could this mean?

The visitors fly away at faster-than-light speeds to visit other stars and solar systems, but return several hundred million years later to see what is happening on the third planet. This time they are astonished to discover that something remarkable has occurred: instead of a sterile environment, the seas now teem with microbial life that has already begun to change the planet's surface and atmosphere. Comets and mete-

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Origin of Cellular Life

orites still bombard the planet, but tens of millions of years separate the giant impacts, and their energies hardly disturb the robust microbial life that has invaded every available niche.

Could their own versions of bacteria have somehow contaminated the planet during their last visit? A bit worried, the visitors again take samples and determine that the new life has an entirely different genetic code than their own, so it is not something they accidentally released. Apparently the spontaneous self-assembly processes they had observed earlier produced enormous numbers of microscopic structures, a few of which increasingly were able to use the energy and nutrients available in the environment to reproduce their structures. But because several hundred million years have passed, the visitors missed the exact point in time at which this occurred! Frustrated, they depart for further exploration, hoping to find other primitive planets where they might have a chance to observe the origin of life. Another 3.5 billion years pass, and they return once again to see what has transpired. By this time, they have discovered that planets with liquid water and life are common in the galaxy, so they are not surprised to find that primitive yet intelligent organisms now inhabit California. When their space ship is observed they must quickly depart, accidentally leaving behind one of their younger family members.

Evidence related to the origin of life

Just kidding about that last part. But even the mythical visitors were astonished, as we should be, that the life process can begin spontaneously on an utterly sterile planet, as long as the environment has liquid water, organic carbon compounds, and energy. How does life begin? This is one of the remaining great questions facing science, a question so daunting that it has tended to inhibit serious scientific inquiry. Even Darwin once noted that "It is as absurd to think about the origin of life as it is to think about the origin of matter." But now, 150 years after Darwin expressed his concern, we do have a pretty good idea about the origin of matter. And we understand living cells in remarkable detail, even to the point that we have begun to manipulate the genetic blueprint of life and will soon know the entire sequence of the 3 billion nucleotide bases in the human genome. But we still do not know how the life process began on the early earth.

On the other hand, we can make some informed guesses — something not possible 50 years ago when the first research on life's origins began. The main point to be made here is that certain kinds of molecules have physical and chemical properties that allow them to self-assemble into orderly structures, and these are the molecules used by living cells. The self-assembly process seems to defy our intuitive expectation from the laws of physics that everything *on average* becomes more disordered — that entropy increases as described by the second law of thermodynamics. For instance, it is easy to calculate that it would be impossible for a specific protein ever to be produced by chance in the lifetime of the universe, and therefore conclude that a supreme being designed all proteins. However, one can make the same argument with a soap bubble. A bubble cannot exist, according to the laws of chance, yet bubbles are a common occurrence.

Several recent scientific advances have provided a more coherent picture of the events leading up to the origin of life. This integrated vision has given rise to a new field called astrobiology, defined as the investigation of life in the universe, and taking into account our new understanding that life on the earth is part of a universal process (see "The astrobiological perspective on life's origin", p 15). The following question-and-answer format indicates that there are things we know with a fair degree of confidence, which now provide a framework for developing and testing hypotheses related to the origin of life.

Where does matter come from?

All atoms heavier than hydrogen and helium, including the biogenic elements carbon, oxygen, nitrogen, phosphorus, and sulfur, are produced in stars by nuclear fusion reactions. The atoms are then blown out into interstellar space

toward the end of a star's lifetime when the star explodes as a nova or, more rarely, a supernova. The atoms then form molecules and dust particles and gather into the enormous clouds that have been imaged by the Hubble Telescope in extraordinary detail. The dust particles, composed largely of silicate minerals, are called interstellar grains. The grains are coated with thin layers of ice and frozen gases like carbon dioxide, carbon monoxide, ammonia, and methanol, as well as a variety of more complex organic compounds. The last point is among the most significant new discoveries about the interstellar medium. That is, organic compounds composed of carbon and the other biogenic elements are not limited to the earth and its neighboring planets in our solar system, but are present wherever stardust gathers into interstellar clouds. We live in an organic universe.

Organic compounds composed of carbon and the other biogenic elements ... are present wherever stardust gathers into interstellar clouds.

Where do stars and solar systems form?

The interstellar molecular clouds are the birthplace of new generations of stars. During star formation, gravity causes portions of the clouds to form rotating disks with the star at the center. Kilometer-sized objects called planetesimals are produced by gravity-driven accretion of dust within the disk, and the planetesimals undergo increasingly violent collisions to produce larger planets. Our own moon is the result of such a collision between the primitive earth and another planet the size of Mars or larger. We now have convincing evidence of a dozen Jupiter-sized planets around other stars, and the search is on for earth-like planets.

What are the sources of organic matter on planets?

During late accretion of earth-like planets, organic compounds and water are delivered to planetary surfaces by cometary and meteoritic infall. Surprisingly, a fraction of the organic compounds are able to stay intact during their arrival in the earth's atmosphere. We can still see the delivery of organic compounds to the earth's surface in the form of carbonaceous meteorites, both large and microscopic. It is likely that other organic compounds were synthesized in the earth's atmosphere, because experiments have been conducted that reproduce the process under simulated prebiotic conditions (see review by Ferris and Hagan 1984). However, because the earth's atmosphere now contains highly reactive oxygen as a result of photosynthetic activity, if organic compounds were synthesized by abiotic processes today, they would be rapidly degraded by oxidation.

What is meant by self-assembly?

Certain organic compounds have the capacity to react with each other to form more complex molecules such as hydrocarbons, amino acids, and simple sugars. Some of these can spontaneously self-assemble into membrane structures, and others can polymerize into molecules similar to proteins and nucleic acids. These in turn form larger self-assembled structures such as the double helix of DNA. Because there were no genes or enzymes available on the prebiotic earth to direct the metabolism and reproduction characteristic of living organisms, the first forms of life must have been produced through a spontaneous self-assembly process.

How did catalytic activity become incorporated into the earliest forms of life?

Most life on the earth today depends on protein catalysts called enzymes, which, like all catalysts, can greatly increase the rates at which reactions proceed. Enzymes also provide specificity to the reaction, because their active catalytic sites typically can only interact with one kind of molecule. Catalysts are essential to life, but what were the first catalysts? They were probably not proteins, because protein synthesis requires DNA, messenger RNA, ribosomes, and chemically activated amino acids — a process much too complex to have occurred spontaneously. However, we now know that certain kinds of ribonucleic acid (RNA) also have catalytic activity, behaving like protein enzymes. These are called ribozymes and considerably simplify our thinking about the beginning of life. We no longer need to suppose that entire cells complete with DNA, RNA, ribosomes, and protein synthesis somehow appeared. Instead, we can conceive of a primitive RNA system that could grow, reproduce and evolve, showing all the properties we associate with the living state.

When did life begin?

Evidence in the form of microscopic fossils has convincingly shown that bacterial life was abundant in shallow seas about 3.5 billion years ago. Other evidence from measurements of stable isotopes of carbon suggest that even simpler forms of life existed 3.8 billion years ago. If so, it follows that life can begin in as little time as 100 million years, since the earth's surface was probably still too hot for any conceivable form of life earlier than 4.0 billion years ago.

Where did life begin?

The origin of life must have occurred in an environment where the temperature was low enough to permit liquid water to exist. Some examples include tide pools or subsurface sites similar to a hydrothermal vent or a geothermal hot spring. Liquid water is required for life as we know it, since only water can provide a universal medium in which self-assembly processes and metabolism can occur. The temperature of the site was likely to have been higher than any prevailing on the earth today. We now know that microbial populations can inhabit environments once thought impossible, where temperatures range up to the boiling point of water. This greatly expands the possible range of sites for the origin of life, and suggests that living microorganisms could be present in deep hydrothermal regions under the

Martian crust, or even on Europa (a moon of Jupiter), which is now believed to have ice-covered oceans of liquid water.

The prebiotic earth

Up until the discovery that microbial life can exist near submarine hydrothermal vents at temperatures above 100°C, the consensus had been that life surely began at the earth's surface. The reasons are easily understood. It seems likely that organic compounds in the prebiotic environment would accumulate as water-soluble compounds and surface films in the early ocean. Fluctuating environments such as tide pools would then provide a mechanism for concentrating the dilute solutions, and, as the concentrated mixtures of organic compounds were dried and heated, an ongoing synthesis of polymeric material would take place (Fox and Harada 1958; Usher 1976).

Recent advances in our understanding of the primitive earth have forced us to rethink this assumption. For instance, the lunar cratering record suggests that the earth was subjected to giant impacts of comets and asteroid-sized objects about the time that the first living organisms appeared. The magnitude of energy associated with such events would vaporize some or all of the early ocean, virtually sterilizing the upper portion of the earth's surface. The origin of life on the surface could only have occurred after the events had ended, a concept now referred to as "impact frustration" of the origin of life (Sleep and others 1989).

The discovery of hydrothermal vents provided an alternative site for life's origin. Shortly after their discovery, Corliss and others (1981) and Baross and Hoffman (1985) proposed vents as a potential site for the first life on the earth. More recently, Stevens and others (1995) reported that hydrothermal regions surprisingly deep in the earth's crust also have extensive microbial populations. Both hydrothermal vents and deep geothermal regions may have provided a refuge from the giant impacts that sterilized the surface of the early earth. This idea is supported by evidence from ribosomal RNA sequences that strongly suggests that the last common ancestor of all life on earth was likely to have been a thermophilic microorganism (Woese 1987; Pace 1991).

A third alternative site was proposed by Bada and others (1994a), who noted that current models of solar evolution predict a young sun 20–30% less luminous than today's sun. Unless there was significant greenhouse warming, the early oceans would freeze to form an ice sheet that would be periodically thawed by impact events. It is well known that organic compounds such as amino acids have finite lifetimes in solution, and their stability decreases markedly as the temperature increases. At the highest temperatures associated with hydrothermal vents, amino acids cannot survive at all (Bada and others 1994b). A global ice cover and colder temperatures would afford significant protection against thermal degradation. It also seems likely that the concentrated mixture of solutes available during thaws could undergo a burst of chemical reactions leading to more complex molecules, a few of which could be on the evolutionary pathway to life.

To summarize, three alternative sites have now been proposed for the accumulation of organic compounds pertinent to the origin of life. Two of the alternatives place the site at the earth's surface, the main variable being the temperature of the site. The third alternative places the site at a subsurface region associated with relatively high temperatures. The surface sites have access to light energy, chemical energy, and concentrating mechanisms, while the subsurface site has access to chemical energy in the form of certain mineral surfaces (pyrite and clays), dissolved gases such as hydrogen and methane, and solutes such as ferrous iron.

The three alternatives do not represent hypotheses per se, but are more in the form of conjectures. That is, they can never be tested by direct experiment, because the origin of life occurred in an unknown environment over 3.5 billion years ago in conditions that cannot be reproduced with certainty today.

How did organic compounds appear on the early earth?

The classic experiments of Miller (1953) showed that impressive yields of certain amino acids can be obtained when a mixture of gases (hydrogen, methane, ammonia, and water vapor) is exposed to an electrical discharge. This discovery represented a major breakthrough, since amino acids are the monomers that combine to make up all proteins. The mixture was assumed to be a simulation of the original terrestrial atmosphere which, by analogy with the outer planets, would have contained hydrogen, methane, ammonia, and water vapor. At sufficiently high energy fluxes, such reducing systems of gases generate hydrogen cyanide (HCN) and formaldehyde (HCHO), which in turn react to produce amino acids. Cyanide and formaldehyde are now considered to be key reactants in simulations of prebiotic chemical pathways (Ferris and Hagan 1984).

The possibility that organic material could readily be synthesized in prebiotic conditions was supported when it was discovered that carbonaceous meteorites also contained amino acids, hydrocarbons, and even traces of purines — one of the basic components of nucleic acids (Kvenvolden and others 1970). If carbonaceous meteorites represent samples of the primitive solar system, it is reasonable to assume that similar synthetic chemical reactions may have occurred on the earth's surface. With organic monomers available in reasonable concentrations on a global scale, it was not difficult to imagine that self-assembling systems of polymerized macromolecules would at some point assume the properties

Three alternative sites have now been proposed for the accumulation of organic compounds pertinent to the origin of life.

of the living state: the ability to exist as a membrane-bounded entity, or cell, the capacity to use energy and nutrients to grow by directed polymerization processes, and the ability to divide in some way to produce another generation.

However, more recent results indicate that the early atmosphere was composed of carbon dioxide and nitrogen rather than a mixture of reduced gases (Holland 1984; Kasting and Ackerman 1986). Carbon dioxide does not support the rich array of synthetic pathways leading to possible monomers, and alternative sources of organic material are being considered. One possibility is that extraterrestrial infall in the form of comets and meteorites provided significant amounts of organic carbon to the earth's surface (Oró 1961; Anders 1989; Chyba and Sagan 1992).

An extraterrestrial source of organic compounds is surprising, but there is no doubt that all of the biogenic elements on the earth (carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur) had an extraterrestrial origin, simply because they were delivered by the earth's accretion process. The question is how much chemical processing occurred before the elements were incorporated into primitive forms of life. Most probably both synthesis and infall were involved to some degree. For instance, amino acids are present only in trace amounts in carbonaceous meteorites, and furthermore are relatively unstable in water. It follows that amino acids and other water-soluble organic compounds probably were synthesized continuously at the earth's surface. On the other hand, hydrocarbon derivatives are relatively stable and compose several percent of the mass of carbonaceous meteorites, yet are not major products of Miller-Urey–type reactions. It may be that hydrocarbons required by early life were primarily delivered with meteoritic infall, rather that being synthesized by terrestrial chemistry.

Estimates of accumulated organic compounds during a 100-million–year late accretion period ending around 3.9 billion years ago are in the range of 10^{16} to 10^{18} kilograms (kg). This is less than the total organic carbon stored as oil shales, coal, and other fossil deposits on the earth (10^{21} kg), which represents carbon dioxide reduced to organic compounds by photosynthetic processes. On the other hand, it is several orders of magnitude greater than the organic carbon now in the biosphere, estimated to be $6{\cdot}10^{14}$ kg. To put this value into perspective, if $6{\cdot}10^{14}$ kg of the organic substances in the total biomass today were spread over the entire surface of the earth, including the oceans, it would form a layer about 1 mm thick. For comparison, the amount of organic substances delivered by infall would form a layer 15–150 times thicker: from 1.6 cm to 1.6 m.

Although this amount of material would represent a significant source of organic carbon in the prebiotic environment if it all survived and accumulated, most of the cometary and meteoritic infall surviving atmospheric entry would presumably fall into oceans. A major fraction of the organic content would be buried as sediment, and a smaller fraction would be released into the marine environment over long time intervals. Water-soluble compounds would dissolve to form a very dilute solution of organic solutes, while longer-chain hydrocarbons and their derivatives would accumulate at the ocean surface to form a thin film at the air–water interface. Such films would likely become concentrated at intertidal zones by the same mechanism that forms sea foam from monolayers of surface active organic compounds today. It follows that probable sites for the physical and chemical processes leading to the origin of living cells would be tide pools or geothermal regions in which hydrocarbon derivatives accumulated and were mixed with water-soluble organic compounds during cyclic drying and rehydration processes.

Self-assembly processes: Soap bubbles and membranes

All life today has units that we call cells. Did life arise from pre-existing cellular structures, or did cellular life develop only at a later evolutionary stage? As noted earlier, there were no large molecules like nucleic acids and proteins available on the prebiotic earth to direct the assembly processes characteristic of life, so the first forms of life must have arisen through self-assembly processes. Familiar examples of such processes today include the formation of bubbles from soap molecules, or the foam that accumulates in tide pools. The main point to be made in this section is that certain kinds of organic compounds called amphiphilic molecules are able to self-assemble into microscopic bubble-like structures. Such structures form spontaneously, and perhaps provided the original membrane-bounded environment required for cellular life to begin.

I will first outline the biophysical principles that govern self-assembly processes and indicate how they can be used to investigate the origin of cellular systems.

Bilayers assemble from a variety of amphiphilic compounds.

Although contemporary cells use phospholipids as the primary component of their two-layered membranes, it is not necessary to think that such complex molecules were required for early cellular life. In fact, simpler amphiphilic molecules can also assemble into bilayer membranes, even single-chain amphiphiles such as soap molecules. It seems likely that primitive cells incorporated lipid-like molecules from the environment as a nutrient, rather than undertaking the much more complex process of synthesizing complex lipids by an enzyme-catalyzed process.

Bilayer permeability strongly depends on chain length of the amphiphilic molecules.

We tend to think of the lipid bilayer as being a nearly impenetrable barrier to ionic solutes such as salt (sodium chloride) and other large, polar molecules like amino acids. But then how did early cellular life function in the absence of highly evolved transport enzymes that transport ionic nutrients and

metabolites across the bilayer barrier? It is true that lipid bilayers of contemporary cell membranes present a significant permeability barrier that is necessary for normal cell functions — particularly those related to bioenergetics of ion transport and chemiosmotic ATP synthesis. However, recent results show that shortening lipid-chain length from 18 to 14 carbon atoms increases its permeability to ionic solutes by several orders of magnitude. This level of permeability is sufficient to encapsulate large molecules such as proteins and polynucleotides, yet still allow external interaction with the encapsulated enzyme. It follows that early cell membranes could have been composed of shorter chain lipids that provided access to nutrients for macromolecules undergoing growth and replication in an encapsulated microenvironment.

Macromolecules can be encapsulated in bilayer vesicles under simulated prebiotic conditions.

A third conceptual problem has been to imagine how lipid bilayers could capture macromolecules in the first place, given that the bilayer must present a nearly impenetrable barrier if the macromolecules are to be maintained within the membrane-bounded volume. We will see how a mixture of lipid and protein or nucleic acids can undergo drying and wetting cycles that simulate tide pools. Under these conditions, the macromolecules are readily captured in membrane-bounded vesicles.

Lipid bilayers grow by addition of amphiphilic compounds present in the environment.

It is not sufficient for a primitive cell to replicate its macromolecular components unless the boundary membrane can increase in area to accommodate the internal growth. Recent experimental results from liposome model systems demonstrate that such growth through addition of amphiphilic molecules can in fact occur.

Self-assembly processes in prebiotic organic mixtures

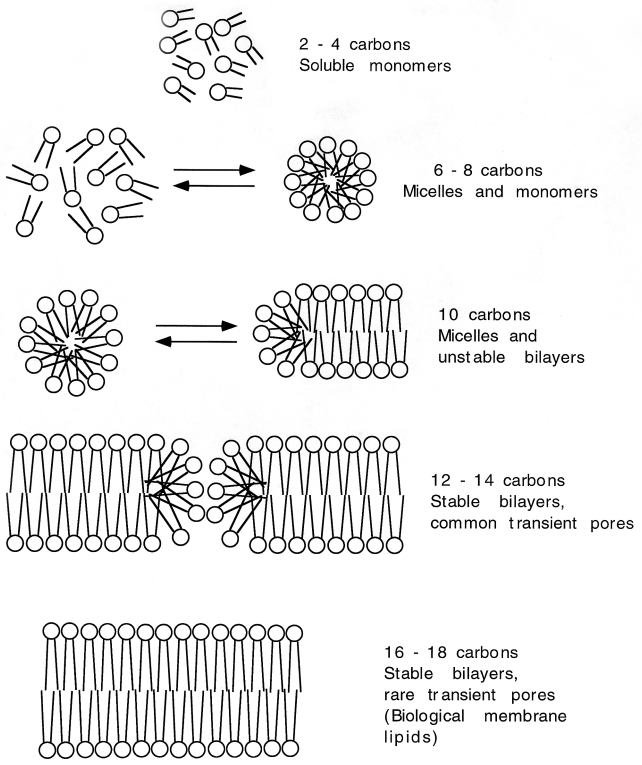


Figure 1.
Self-assembly of amphiphilic molecules.

Molecules that have both hydrophobic (water-repelling) and hydrophilic (water-attracting) groups are called amphiphilic. The hydrophobic group is typically a hydrocarbon chain, and the hydrophilic group can be any polar or ionic compound. Common examples of amphiphilic substances are soaps and detergents. Membrane lipids are also amphiphilic, and usually contain two hydrocarbon chains as shown in this figure. When the chains are relatively short, containing 2–4 carbon atoms, the molecules are soluble in water. As chain length increases to 6–8 carbons, water solubility decreases, and above certain concentrations the molecules begin to aggregate into micelles. Lipids with chain lengths around 10 carbons begin to form both micelles and bilayer structures, and bilayers dominate the structures produced by lipids with 12–14 carbons. Significantly, such bilayers are "leaky" to ions that are otherwise unable to pass through the membrane due to the transient micelle-like pores that commonly occur in the structure. This fact is important in the model protocells that will be discussed later. Chain lengths in the range of 16–18 carbons are predominant in biological lipids, and the resulting bilayers are very stable and relatively impermeable to ionic flux.

The first suggestion that membranes played a role in the origin of life was in JBS Haldane's prescient note in *The Rationalist Annual* (1926). Haldane wrote: "The cell consists of numerous half-living chemical molecules suspended in water and enclosed in an oily film. When the whole sea was a vast chemical laboratory the conditions for the formation of such films must have been relatively favorable ..." Goldacre (1958) proposed that the first membranes could have been produced by wave action disturbing films of lipid-like surfactants. The first experimental approaches to this question were undertaken by Hargreaves and others (1977) and Oró and others (1978).

What physical properties are required if a molecule is to become incorporated into a stable bilayer? All bilayer-forming molecules are amphiphiles, with a hydrophilic "head" and a hydrophobic "tail" on the same molecule. Although we tend to think of membrane lipids as being limited to phospholipids and cholesterol, in fact a surprising variety of amphiphiles take part in membrane structure, including sphingolipids, cerebrosides, other sterols, and pigments like chlorophyll. Earlier studies (Hargreaves and Deamer 1978) showed that even single-chain amphiphiles, such as alkyl phosphates, alkyl sulfates, and fatty acids, can assemble into bilayer membranes if they contain 10 or more carbons in their hydrocarbon chains (Figure 1).

If amphiphilic molecules were present in the mixture of organic compounds available on the early earth, it is not difficult to imagine that their self-assembly into molecular aggregates was a common process. Is this a plausible premise? A reasonable start is to assume that the mixture of organic compounds in carbonaceous meteorites resembles components avail-

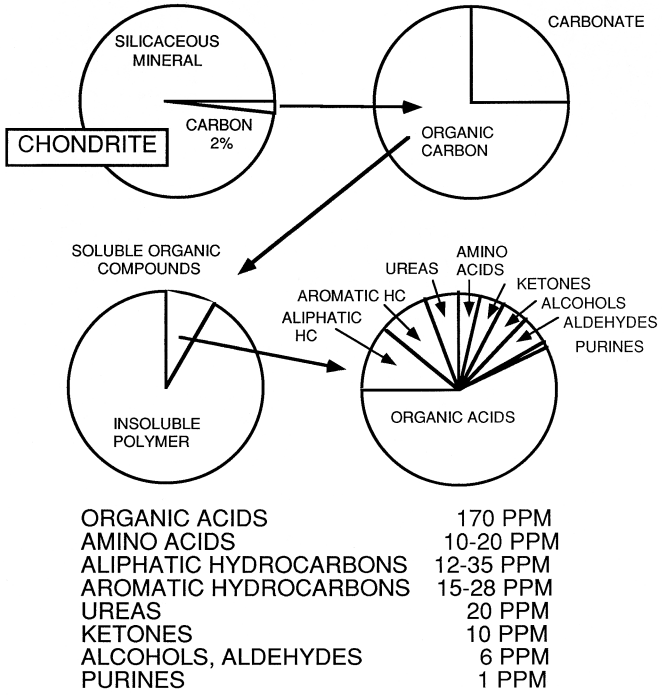


Figure 2.

Organic compounds are present in carbonaceous meteorites. These were synthesized by abiotic reactions that occurred in the meteorite parent body during the earliest stages of solar system formation, and were likely delivered to the early earth in substantial amounts, mostly in the form of micrometeorites and comets. See text for details.

able on the early earth through extraterrestrial infall. Most meteorites are composed of silicon-based minerals, and a small fraction (~5%) of these stony meteorites contain up to several percent of their mass in the form of organic carbon. These are referred to as carbonaceous meteorites, and their organic compounds are actual samples of the chemical components of the early solar system. A kerogen-like insoluble polymer composed largely of covalently linked polycyclic aromatic hydrocarbons is the most abundant organic material, while a series of organic acids (including 10–20 ppm of amino acids) represents the most abundant water-soluble fraction (Figure 2). Aliphatic and aromatic hydrocarbons, ureas, ketones, alcohols, aldehydes, and purines are also present (see Cronin and others 1988 for review).

A variety of amphiphilic molecules could also be present in the form of polar hydrocarbon derivatives. We therefore extracted samples of the Murchison carbonaceous chondrite in the standard chloroform-methanol-water system used to extract membrane lipids from tissues. Two-dimensional thin layer chromatography showed that a complex mixture of oxidized aliphatic and aromatic hydrocarbons was present. When this material was allowed to interact with aqueous phases, one class of compounds with acidic properties was clearly capable of forming membrane-bounded vesicles (Figure 3). The vesicles responded osmotically to sodium chloride or sucrose additions, and could maintain gradients of a negatively charged fluorescent dye (pyranine). This provides strong evidence that a mixture of abiotic organic compounds isolated from a carbonaceous meteorite contains amphiphiles capable of forming membranes.

Using mass spectrometry and infrared spectrophotometry (FTIR), we determined that one of the components of the mixture was nonanoic acid, a 9-carbon carboxylic acid. Nonanoic acid has too short a chain to form stable bilayers, but at neutral pH and high concentration of the amphiphile, membrane structures are readily observed by light microscopy (Figure 4). On this basis, we assume that the meteoritic amphiphiles contain a mixture of monocarboxylic acids such as nonanoic acid, together with polar polycyclic aromatic compounds that produce the characteristic fluorescence of the vesicle structures. Because only microscopic quantities of the membrane-forming components are available, we have not been able to directly analyze the membranes themselves.

To summarize these results, amphiphilic compounds capable of membrane formation are present in carbonaceous meteorites and are able to self-assemble into bilayer membranes. The amount of such compounds in the carbonaceous meteorites is relatively small, and we do not propose that this represents an abundant source of lipid-like material on the early earth. However, the observation that membranes can self-assemble

continued on page 31

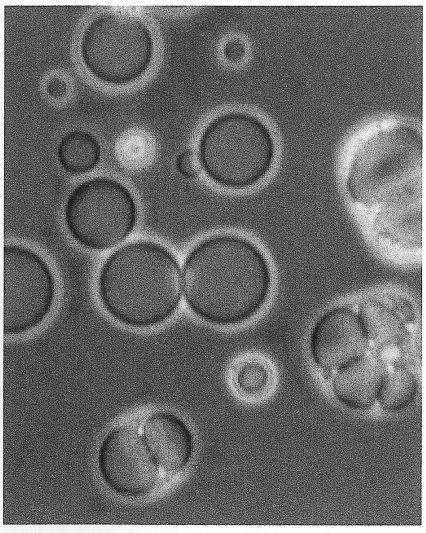
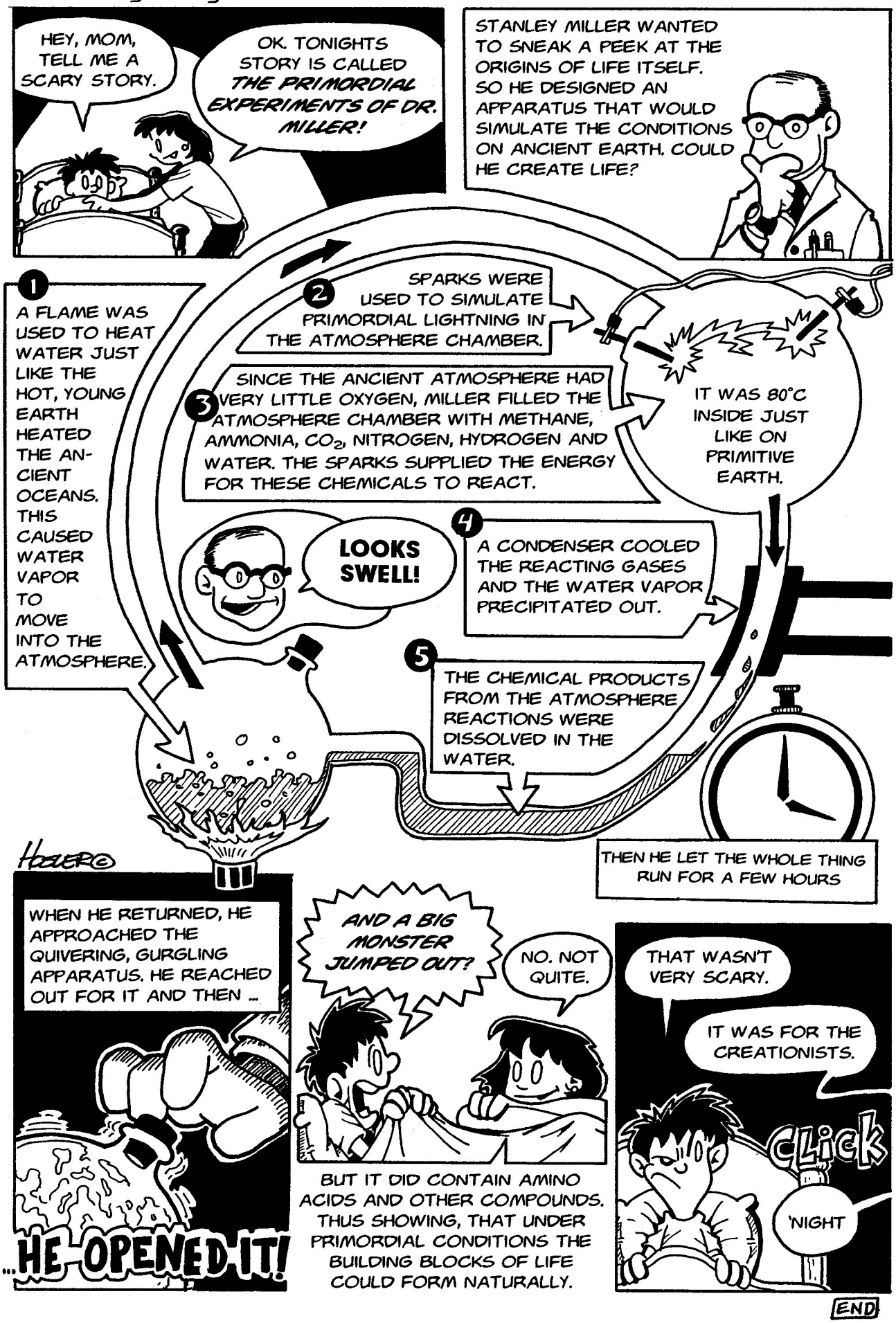


Figure 3.

Self-assembled vesicular structures are produced by organic compounds extracted from the Murchison carbonaceous meteorite when they interact with water. The vesicles are 10–50 micrometers in diameter and are bounded by bilayer membranes that can act as a diffusion barrier to ionic flux. Such relatively impermeable boundary structures are essential to the membranes that define all cellular life today.
LEFT: phase micrograph.
RIGHT: light micrograph showing the natural fluorescence of the vesicles. The fluorescence is caused by polycyclic aromatic hydrocarbons that are abundant in carbonaceous meteorites.
Original magnification: 400%.

The Scary Story



The Buck Starts Here

If all you knew about the scientific study of the origin of life were what the "intelligent design" documentary *Unlocking the Mystery of Life* told you, you would think that the field was moribund after Dean Kenyon abandoned it in the mid-1970s (and subsequently coauthored the "intelligent design" textbook *Of Pandas and People*). But as J William Schopf explains in his introduction to *Life's Origin* (described below), "an overall picture of how life emerged is achieving ever-clearer focus. But the search for deep knowledge of the processes involved, an understanding of the details of each step, is a work in progress. With active research dating only from the 1950s, the field is young, vibrant, and advancing rapidly." It is unwelcome news to creationists, of course, but those of us interested in defending the teaching of evolution in the public schools are likely to have a different reaction altogether. To review the latest in origin-of-life research, its cousin astrobiology, and the history of scientific investigation of the origin of life, consult the following books, now available through the NCSE web site: <http://www.ncseweb.org/bookstore.asp> — look in the "In the latest *RNCSE*" section. And remember, every purchase benefits NCSE!

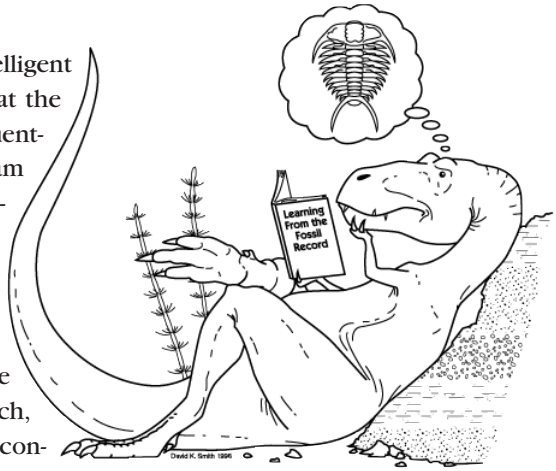


Illustration by Dave Smith, used with permission of the University of California Museum of Paleontology.

Different Approaches

Seven Clues to the Origin of Life: A Scientific Detective Story
by AG Cairns-Smith
In *Genetic Takeover* (Cambridge: Cambridge University Press, 1982), Cairns-Smith argued, in full technical detail, that life was originally based on self-replicating inorganic crystals. *Seven Clues to the Origin of Life*, originally published in 1985, presents his hypothesis at the popular level, engagingly written with ubiquitous references to the methodology of Sherlock Holmes. *Seven Clues to the Origin of Life* "is a summary of the best evolutionary thinking as applied to the origins of life in which the important issues are addressed pertinently, economically, and with a happy recourse to creative analogies", wrote the reviewer for *Nature*.

Origins of Life
by Freeman Dyson
In *Origins of Life*, the renowned theoretical physicist Freeman Dyson, Emeritus Professor at the Institute for Advanced Study in Princeton, turns his attention to the origins of life, proposing (as the plural in the title suggests) a dual account: "life began twice, with two separate kinds of creatures, one kind capable of metabolism without exact replication and the other kind capable of replication without metabolism." The reviewer for *Scientific American* writes, "Dyson builds his argument with characteristic skill and clarity." Originally published in 1985, *Origins of Life* was extensively revised in light of subsequent scientific research for the 1999 edition. (*Origins of Life* is reviewed on p 48).

The Origin of Order: Self-Organization and Selection in Evolution
by Stuart A Kauffman
Can life self-organize? So Kauffman suggests in his presentation of a non-Darwinian, but nonetheless evolutionary, explanation for the origin of life and early molecular systems. "Has there been time, since the origin of life on earth, for natural selection to produce the astonishing complexity of living organisms? Kauffman offers a new and unorthodox answer to this question. Given what we know about the way genes signal to one another, he argues that complexity can arise more readily than one would expect. I am not sure he is right, but I am sure that we should take his ideas seriously", writes John Maynard Smith.

Biogenesis: Theories of Life's Origin
by Noam Lahav
From the publisher, Oxford University Press: "*Biogenesis* provides an up-to-date and detailed discussion of the interdisciplinary study of the origin of life, including in-depth investigations into its history, assumptions, experimental strategies, theories, models, and controversies. Written both critically and objectively, the book explores topics including the history of the search for life's origin from the Greek philosophers to contemporary scientists; selected attributes of life which are connected to theories of biogenesis; the main features of our solar system and earth, where life is assumed to have originated; and the rationale and strategies of scientific theories of the origin of life."

Life's Origin: The Beginnings of Biological Evolution
edited by J William Schopf
Containing essays by leading figures — John Oró, Alan W Schwartz and Sherwood Chang, Stanley L

<http://www.ncseweb.org/bookstore.asp>

Miller and Antonio Lazcano, James P Ferris, Leslie E Orgel, and J William Schopf himself — *Life's Origin* provides a lively look at the state-of-the-art in the scientific study of the origin of life. In his introduction, Schopf lists "the three great puzzles this volume addresses: *What* is the origin of life, *when* did it begin, and *how*?" and expresses his confidence that "[g]iven time, effort, and a continuing influx of imaginative students and fresh ideas, we can one day fully answer the *what, when,* and *how* of life's beginnings."

The Spark of Life: Darwin and the Primeval Soup
by Christopher Wills and Jeffrey Bada
"Life as we know it is assertive, demanding, and unstoppable", Wills and Bada write in *The Spark of Life*. But how did it get started? The authors defend the "primeval soup" model against its competitors, extending it with suggestions of their own. The reviewer for *Nature* writes, "They entertain by not only giving a lively description of the 'spark of life', but also by conveying the sparkle of its investigators and the nature of the scientific process. These two professors have written a book that reads like a novel, and one would be happy to have them educate one's children." (*The Spark of Life* is reviewed on page 47.)

Beyond the origin

Vital Dust: Life as a Cosmic Imperative
by Christian de Duve
Dedicated simply to life, *Vital Dust* "seeks to retrace the four-billion-year history of life on earth, from the first biomolecules to the human mind and beyond" in a wholly naturalistic framework, eschewing vitalism, finalism or teleology, and creationism. The first three parts of the book ("The age of chemistry", "The age of information", and "The age of the protocell") constitute a beautifully written introduction to research on the origin of life and the earliest forms of life. De Duve shared the 1974 Nobel Prize for Physiology or Medicine with Albert Claude and George Palade for their discoveries concerning the structural and functional organization of the cell.

Cradle of Life: The Discovery of Earth's Earliest Fossils
by J William Schopf
"This book chronicles an amazing breakthrough in biologic and geologic science", Schopf writes, "the discovery of a vast, ancient, missing fossil record that extends life's roots to the most remote reaches of the geologic past. At long last, after a century of unrewarded search, the earliest 85% of the history of life on earth has been uncovered to forever change our understanding of how evolution works." Writes the reviewer for *Scientific American*, "Schopf ... has a good deal to say about scientists and the way science is done. It all makes for a book that bears out his assertion that 'science is enormously good fun!'"

Astrobiology

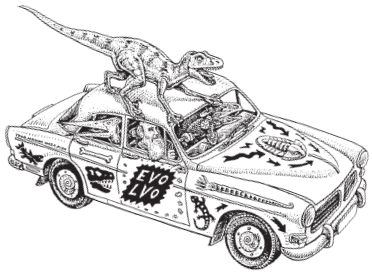
Life Everywhere: The Maverick Science of Astrobiology
by David Darling
In *Life Everywhere*, Darling offers a highly readable introduction to the burgeoning science of astrobiology, lucidly explaining its purview, goals, and methods, and offering his own predictions about what is in store. Darling, who has a DSc in Physics and a PhD in astronomy, relies not only on his own knowledge but also on extensive interviews with the movers and shakers in astrobiology. He also exposes the creationist roots of the "rare earth" hypothesis. "Darling's book serves as an enthralling introduction to the new science of astrobiology and the old, still exhilarating philosophical question of our place in the universe", writes Lynn Margulis.

Astrobiology
by Monica M Grady
In her brief but lavishly illustrated introduction to astrobiology, published by the Smithsonian Institution Press, Grady starts at the very beginning: the Big Bang. She then lucidly discusses the conditions necessary for the emergence of life, considering both the early earth and the possibility of life elsewhere in the solar system, as well as the search for life beyond the solar system. Writes the reviewer for *Nature*, "The broad expertise involved in astrobiology is always a challenge and even 'experts' will benefit from such an informative overview." Grady is Head of the Petrology and Meteoritics Division of the Natural History Museum in London.

The Historical Picture

The Emergence of Life on Earth: A Historical and Scientific Overview
by Iris Fry
Fry, a historian and philosopher of science, offers a unique scholarly perspective on the scientific issues involved in research on the origins of life. In addition to summarizing the history, all the way from Aristotle through Darwin and Pasteur to Oparin, Haldane, and Miller, she examines the contemporary issues and debates within the origin-of-life scientific research community. The reviewer for the *Journal of the History of Biology* praises *The Emergence of Life on Earth* for "raising important questions in a way fully up to date with current discourse in both history and philosophy, and integrating these approaches throughout the book." (*The Emergence of Life on Earth* is reviewed on p 46.)

Origin of Life
by AI Oparin
Inspired by Darwin and Mendeleev, Aleksandr Ivanovich Oparin (1894–1980) was one of the first scientists to propose that the origin of life on earth was preceded by a period of nonbiological molecular evolution. *Origin of Life*, published in English in 1938 and still in print, "purports to show the gradual evolution of organic substances and the manner by which ever newer properties, subject to laws of a higher order, were superimposed step by step upon the erstwhile simple and elementary properties of matter." Written for a general audience, *Origin of Life* remains a classic introduction to origin-of-life research.



NCSE on the Road

A Calendar of Special Events, Presentations, and Lectures

Date November 2, 2003
City Seattle WA
Presenter Eugenie C Scott
Title Evolution and Creationism: What is the Role of the Scientist?
Event Panel discussion at the annual meeting of the Geological Society of America
Time 12:00 noon
Location Washington State Convention and Trade Center
Contact Frederick L Schwab, schwabf@wlu.edu

Date November 5, 2003
City Seattle WA
Presenter Eugenie C Scott
Title Stasis and Evolution in Grassroots Creationism
Event Symposium presentation at the annual meeting of the Geological Society of America
Time 12:00 noon
Location Washington State Convention and Trade Center
Contact John Bratton, jbratton@usgs.gov

Date November 15, 2003
City Kansas City MO
Presenter Eugenie C Scott
Title Issues and Answers in Teaching Evolution
Event NSTA Midwest Regional Conference
Time TBA
Location Kansas City Marriott Hotel
Contact Carol Williamson, williamso@mail.olathe.k12.ks.us

Date December 4, 2003
City San Francisco CA
Presenter Eugenie C Scott
Title Choosing Controversial Issues for the K–12 Classroom
Event K–12 Outreach Luncheon Keynote Address at the annual meeting of the ASCB
Time 1:45 PM
Location Moscone Center
Contact Kenneth R Miller, kenneth_miller@brown.edu

Date January 16, 2004
City Las Vegas NV
Presenter Eugenie C Scott
Title Tracking Those Incredible Creationists
Event The Amazing Meeting II, sponsored by the James Randi Educational Foundation
Time 10:45 AM
Location Tuscany Hotel and Casino
Contact James Randi, randi@randi.org

Date February 27, 2004
City Hamilton NY
Presenter Eugenie C Scott
Title How Politics Affects Evolution Education
Event A lecture sponsored by the Department of Education of Colgate University
Time TBA
Location Colgate University
Contact Ernie Nolan, enolan@mail.colgate.edu

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

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continued from page 26

from the amphiphilic components at least makes it more plausible that membrane-bounded structures were present at the time of life's origin.

A MODEL PROTOCELL

The fact that amphiphilic compounds present in meteorites can self-assemble into bilayer membranes makes it plausible that lipid-like molecules were available on the early earth and could provide the first cellular boundary structures. The next step is to develop laboratory models of simple cellular systems in which macromolecules are encapsulated by lipid bilayers.

Liposomes are self-assembled spherical lipid bilayers in the size range of bacteria and provide a useful model system for studies relating to the origin of cellular life. Liposomes are able to capture large molecules such as enzymes and nucleic acids, but their bilayers are relatively impermeable to smaller polar and ionic solutes. In contemporary cells, growth and reproduction require the transport of nutrients across the cell membrane, and employ complex protein assemblies to facilitate the transport process. Before such proteins had evolved, what mechanism was available to transport the nutrients required for cell growth?

We have found that bilayer permeability is strongly dependent on chain length. That is, shortening the chains of a given membrane lipid dramatically increases rates of transport of ionic solutes (Paula and others 1996). We therefore prepared liposomes with lipids of intermediate chain length (14-carbon chains). These liposomes can efficiently encapsulate enzymes, yet are permeable enough to allow influx of an externally added substrate molecules.

We first chose to encapsulate an RNA polymerase called polynucleotide phosphorylase (Chakrabarti and others 1994). This enzyme does not depend on a template to synthesize RNA. Instead, it can use nucleotide diphosphates such as ADP as both an energy source and a monomer to be incorporated into an RNA strand (Figure 5.1). In a typical experiment, the enzyme was captured in liposomes by a simulated tide pool cycle in which a mixture of the enzyme and lipids was first dried, then rehydrated in the reaction medium. Under these conditions about half of the original enzyme can be encapsulated. ADP was added to the external medium, and after an incubation period RNA synthesis was monitored both by microscopic methods and by gel electrophoresis. We found that vesicles containing the enzyme synthesized so much RNA that it could be seen inside the liposomes when stained with a fluorescent dye and then observed by fluorescence microscopy. Recently we have succeeded in capturing a more complex system that includes both a catalytic polymerase and a DNA template that acts as a kind of "gene" to direct the synthesis of RNA (Monnard and others 1999). Under these con-

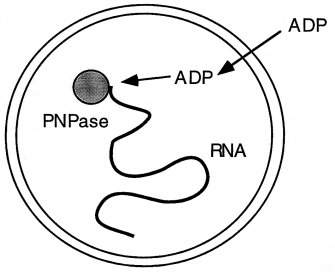
FIGURE 5.
ENCAPSULATED RNA POLYMERASE ACTIVITY.

FIGURE 5.1.

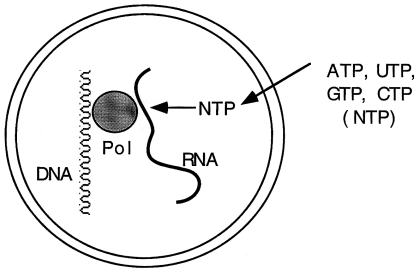
Polynucleotide phosphorylase synthesizes RNA using adenosine diphosphate (ADP) as a substrate. The ADP can reach the enzyme by passive diffusion through transient defects in the lipid bilayer.

FIGURE 5.2.

T7 RNA polymerase uses a DNA template to direct the synthesis of RNA, and has recently been shown to synthesize RNA inside liposomes, as illustrated in the figure. Synthesis of RNA molecules by transcribing the base sequence from a DNA template is a basic function of all cellular life.



5.1 Encapsulated polynucleotide phosphorylase (PNPase)



5.2 Encapsulated T7 RNA Polymerase (Pol)

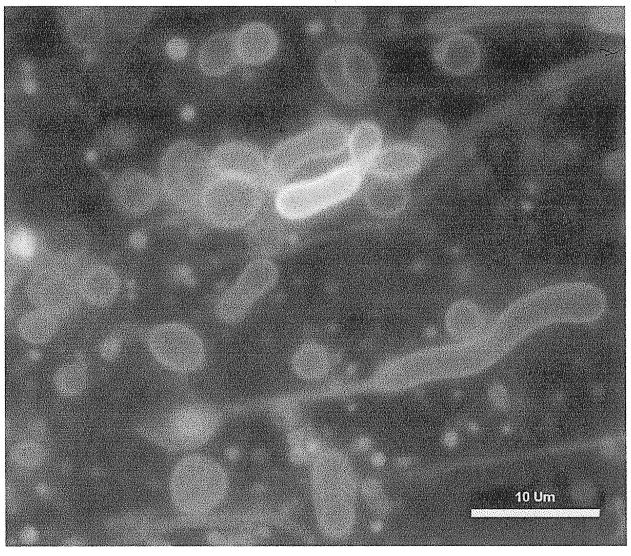


FIGURE 4.

Membranous structures produced by nonanoic acid, one of the amphiphilic components present in the mixture of compounds extracted from the Murchison meteorite. Conditions: 100 mM sodium nonanoate at pH 6.9. Original magnification: 400%

ditions, a specific transcript of RNA is transcribed from the DNA template by the polymerase, and the RNA can again be visualized by fluorescence microscopy (Figure 5.2).

These results provide a useful perspective on substrate transport by primitive forms of life. In the early earth environment, there must have been a variety of amphiphilic hydrocarbon derivatives that could self-assemble into bilayer boundary structures. However, it is not necessary to think that the structures were of the same length and permeability properties of contemporary membranes. Instead, membrane-forming amphiphiles with 12–14 carbon chains, modeled here by DMPC, would produce bilayers that are permeable enough to allow passage of ionic substrates required for polymerization of macromolecules such as RNA, yet maintain those macromolecules within a boundary. Encapsulated catalysts and information-bearing molecules would thus have access to nutrients required for growth. Furthermore, specific groupings of macromolecules would be maintained, rather than drifting apart. This would allow true selection of such groupings to occur, a process that could not as easily take place in mixtures of molecules free in solution.

Can life be made in the laboratory? Future directions.

These principles can be applied to propose a laboratory version of a protocell. Such a molecular system should meet the following conditions:

A polymer such as a nucleic acid must be replicated by a template-directed polymerization process. The polymer must be able to contain one or more sequences of monomers that correspond to genetic information.

A catalytic activity must be present that is somehow linked to the replication process, so that variations in replication affect the rate or efficiency of the catalyzed reaction. The catalyst must also be reproduced by the polymerization process, using the genetic information in the polymer.

The replication and catalytic system must be compartmentalized within a membrane-bounded volume so that selection of variations can lead to "speciation" of the encapsulated genetic material.

The boundary membrane itself must be able to grow. This could be accomplished either by accumulation of amphiphiles from the environment or by conversion of precursor molecules into amphiphiles. Furthermore, the growth must somehow be coupled to the replication process so that it neither lags behind nor gets too far ahead of the RNA production.

There must be a mechanism that allows the assembly to break up into smaller structures when it reaches a given size, and the smaller structures in turn should incorporate the capabilities of the larger system.

Is there any hope that such an assemblage of molecules might be established in the near future? We can begin by considering ribozymes, which are strands of RNA with catalytic sites resembling those of enzymes. Because ribozymes have the potential to act both as catalysts and carriers of genetic information, they have been proposed as the primeval genetic material (Joyce and others 1987). In one laboratory model of a replicating RNA system, a reverse transcriptase first produces a DNA strand by using a specific ribozyme as a template, and a second DNA polymerase makes multiple copies from the DNA, thereby amplifying the original RNA strand thousands of times as the cycle is repeated. Significantly, the ribozyme itself can also evolve under these conditions when a suitable selective pressure is present. For example, Beaudry and Joyce (1992) found that it was possible to produce a specific catalytic site on a ribozyme by continuously selecting for that site with biochemical hurdles, a kind of molecular breeding carried out in the test tube. Wilson and Szostak (1995) went on to show that a specific catalytic site could be selected from a mixture of trillions of random RNA sequences, a process like the kind of selection that would have occurred in an population of early molecules competing for a resource.

Could such ribozyme systems be considered to be alive in some sense? After all, the RNA is capable of growth and evolution, two primary properties of the living state. However, the system falls short of the definition of life for at least two reasons. First, the ribozyme amplification requires protein enzymes that do not themselves replicate. And second, the test tube acts as a macroscopic encapsulated environment that maintains the system components in contact with one another while the investigator adds monomers and energy. If the components were released from the bounds of the test tube environment, they could not function.

But what if we encapsulated ribozymes in liposomes? It is not at all difficult to set up a system of encapsulated ribozymes so that each liposome contains a different RNA sequence, each with the potential to exhibit a different catalytic activity. Then we might be able to select for a ribozyme that had polymerase activity, because only that liposome would contain RNA, even though no protein enzyme was present. We might also select for a ribozyme that could catalyze the synthesis of phospholipid from activated intermediates such as acyl coenzyme A and a lysophosphatide. Again, only that liposome would increase in volume, because only such a liposome would be able to synthesize membrane components from non-membranous precursor molecules. None of the proposed ribozyme catalysts has yet been discovered, although a polymerase-like activity in certain ribozymes has been observed (Been and Cech 1988). Furthermore, virtually nothing is known about the interactions of ribozymes in catalyzing a lipid synthesis reaction. Nonetheless, this thought experiment shows that it

is at least possible to conceive of a cellular life form with RNA catalysts that has the potential to be modeled under laboratory conditions. Further investigations of encapsulated replicating catalytic systems will help us to better understand what happened over 3.5 billion years ago as self-assembled molecular systems first began to grow, reproduce, and evolve toward the earliest forms of microbial life.

Acknowledgments

[*Portions of this article were adapted from reviews published elsewhere (Deamer 1998, 1999). This version was based on a chapter of the same name, in Springer D, Scotchmoor J, eds.* Evolution: Investigating the Evidence*. College Park (PA): Paleontological Society Press, 1999.*]

It's an Old World After All

For a review of the astronomical evidence relevant to the age and the development of the universe, along with resources especially for teachers, see "An ancient universe: How astronomers know the vast scale of cosmic time", by Andrew Fraknoi, George Greenstein, Bruce Partridge, and John Percy, published as a special issue of *The Universe in the Classroom* (2001 Fall: 56; available on-line at <http://www.astrosociety.org/education/publications/tnl/56/index.html>), the Astronomical Society of the Pacific's newsletter on teaching astronomy in grades 3–12, and under the auspices of the American Astronomical Society's Astronomical Education Board. The article begins with an overview of the universe and the nature of science, then explains how scientists have been able to ascertain the age of the universe and what changes have taken place in it over time, and concludes with a brief discussion of science and religion. Two appendices provide a resource guide and educational activities.

[*Thanks to Andrew Fraknoi.*]

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Astrobiology and the Search for Alien Life

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In another paper in this issue (p 15), I described astrobiology and discussed the ways this field relates to the study of the origin of life on earth. In this paper, I touch on other aspects of astrobiology: studying life in extreme conditions on earth and the initial efforts to search for evidence of life beyond our planet.

In the previous paper, I noted the difficulty of understanding the origin of life, since there is almost no direct evidence from either geological or genetic studies on the first half-billion years of terrestrial history. Here we pick up the story after the emergence of simple cells that already have DNA and RNA and thus are subject to selection as they reproduce and evolve.

Evolution on earth: The highlights

Astrobiology brings a multidisciplinary perspective to biology, as well as to comparing our planet with other potential abodes of life. Someone looking at the history of life from this perspective quickly focuses on microbes. Most of life's history took place before the first multicellular organisms appeared. Most life today (whether measured by biomass or diversity or chemical interaction with the atmosphere) is still microbial. It is probably microbes, not "little green men", that we will find when we encounter life on other planets.

Remarkably, the vast majority of microbial life on earth is unknown — recent experiments in molecular taxonomy suggest that fewer than 1% of the microbes in any random sample belong to previously identified or cultured species.

Many popular texts still refer to the microbes as "primitive" and comment on the sluggish pace of evolution prior to the Cambrian explosion. Evolution is sometimes treated as if it did not really begin until the most recent billion years of earth history, and there is an understandable emphasis in museums and popular-level books on evolution of the larger creatures, such as the dinosaurs, or the "smarter" ones, such as dolphins and apes.

When we look at the molecular phylogenetic tree, however, we see hints of a rich evolutionary history spanning the 3 billion years between the emergence of earliest living things and the Cambrian explosion. On the modern tree of life, the metazoans — from mollusks to mammoths — are banished to just a few twigs. From a functional point of view, also, it can be argued that the development of metazoans was just the most recent of several critical milestones in evolutionary history.

The earliest major innovation was the invention of photosynthesis. This may have happened as long as 3.5 billion years before the present (BP). Before that time, living cells had to extract energy (as many still do today) from chemical disequilibria in their surroundings, such as those produced when superheated water dissolved chemicals from the crust in regions of hydrothermal activity. Such strategies are much less efficient than photosynthesis. Once living things developed the complex sequence of chemical reactions that allowed chemical energy to be extracted directly from sunlight, a grand new world of possibilities opened. One of the most important questions in the search for life elsewhere involves our expectations concerning the emergence of photosynthesis on other worlds.

The second great leap, which may have happened at about the same time as photosynthesis, was the emergence of the Eukarya — cells larger and more complex than the prokaryotes (Bacteria and Archaea). Eukaryotic cells contain functionally distinct subunits: a nucleus enclosing genetic information, plus various mitochondria and (for plants) chloroplasts. These microbes are among life's most successful groups, especially the ubiquitous protists (including amoebae, diatoms, paramecia, and foraminifera). Almost certainly the Eukarya originated in the merging or envelopment of various bacteria; for example, the chloroplasts in many ways resemble cyanobacteria. There is a crucial difference, however, because in the Eukarya the genetic information for each of the subunits as well as for the cell as a whole is combined in the nucleus. Their origin marks a fundamental change in the functionality of the genome.

The third milestone was the invention of sexual reproduction, which happened roughly 2 billion years BP. Certain eukaryotes developed double strands of genes (providing redundant information storage). The next step was to find a way of combining genes from two parents, rather than simply cloning the cell. Sexual reproduction allowed greater genomic diversity, since offspring are not genetically identical. This diversity of populations enhanced the opportunities for selection to favor some genetic combinations over others and accelerate the pace of evolution.

The fourth and final great innovation was multicellular or pluricellular organisms. Sometime before 0.7 billion years BP, life evolved the capability to store and use the genetic information for multiple types of cells within its germ cell. Now a variety of cells types could be manufactured from a single source of genetic information through sophisticated control of gene expression. Once this capability existed, it was relatively simple for these different cell types to form tissues and to link up within a single organism. Thus metazoans — multicellular organisms with cells organized into tissues — became possible.

The preceding is a crude, macroscopic perspective on evolution. When we consider the possibility of life on other worlds, even life that is chemically similar to our own, we must ask ourselves which of these key steps — photosynthesis, multicomponent cells, sexual reproduction, and multicellular organisms — might have taken place there. Our ability to detect and recognize alien life depends on these or similar evolutionary events.

Habitable environments on earth and beyond

To understand the role of life in the universe, we must explore the range of environments that might support living things. Astrobiologists approach this problem in two ways. In this section, I discuss habitability from the perspective of the basic properties of carbon-based life. In the next section, I look at the diversity of environmental conditions on earth where life is found.

Most astrobiologists limit their consideration to carbon chemistry because carbon is abundant and more capable than any other element of forming a wide variety of complex chemical bonds. Besides, carbon-based life is the only sort we could confidently recognize.

Much of organic chemistry is enabled by the presence of liquid water. Water is the best solvent, which is why we use it for washing. The range of temperatures in which water is a liquid (from 0° to 100°C) is precisely the range in which much of carbon-based chemistry is active. At temperatures above 100°C the larger carbon molecules start to come apart, which is why boiling water kills most microbes.

While water molecules are abundant in the universe, liquid water is much less so. Most places are either too hot or too cold. In addition, liquid water requires an ambient pressure greater than 0.006 bars (4.5 mm of mercury); at lower pressures, water can have only two states: solid and gas. The requirement for liquid water directs our attention toward planetary surfaces with temperatures between 0° and 100°C.

In addition to liquid water and organic chemicals, life requires an energy source. Early life on earth extracted energy from dissolved chemicals through fermentation and other reactions. Photosynthesis, however, enables life to tap the much greater energy of sunlight itself. Photosynthesis yields carbohydrates and oxygen gas as byproducts, and these can be used as an energy source by other organisms, such as animals.

A habitable environment, then, seems to require the presence of 3 things: abundant raw material in the form of carbon compounds, liquid water (which points us toward planets), and an exploitable energy source.

Life in extreme conditions

On earth, life has evolved to fill many ecological niches, some of them quite different from our everyday experience. Organisms that live and flourish in such environments are called extremophiles — meaning that their environments seem extreme to us. Most extremophiles are microbes, but these are not necessarily simple or primitive — in fact, a great deal of evolutionary adaptation was required for them to function in these environments.

Most life works best at temperatures between about 15°C and 60°C. Microbes that prefer lower temperature are called psychrophiles, and those that prefer heat are called thermophiles. At the low end, life can often survive at temperatures even below 0°C, although metabolism slows down or stops. Microbes that were frozen and dormant for tens of thousands of years in the Antarctic ice have been revived in our laboratories.

At high temperatures, thermophiles have developed mechanisms to make the chemical repairs that are needed as carbon-based compounds begin to come apart. Unlike the dormant state at low temperatures, adaptation to high temperatures requires active chemical intervention. For example, many microbes flourish in the Yellowstone hot springs at temperatures up to 100°C. The record for a thermophile is 113°C at deep-sea vents. (Note that the pressure of the water above the vent is so great that 113°C is still below the boiling point of water there.)

Other environmental extremes involve moisture, salt, and acid. Many microbes tolerate desiccation in much the way they survive low temperatures, by going into a dormant state and waiting for better conditions to return. Some microbes are so tolerant of high salinity that they can live even in the waters of the Dead Sea. The range of acidity in which life has been found goes from pH less than 0 to greater than 9. One example of an acid environment is the Rio Tinto of southern Spain, which originates in a region of extensive mineral deposits and maintains a steady pH of 2.5 all the way to its mouth (by comparison, lemon juice has a pH of 2). A rich microbial community inhabits this river, with some of the microbes helping to maintain the acidity, because that is the environment they like.

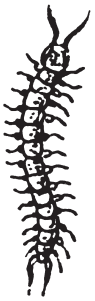
One of the most surprising cases of tolerance to extremes is exhibited by an "atomophile": the bacterium *Deinococcus radiodurans*, which is found (among other places) in the cooling water of nuclear reactors. With its highly developed chemical repair mechanisms, *D radiodurans* can survive ultraviolet or particle radiation up to 6000 rads per hour, a thousand times more than a human can tolerate. It is also resistant to many unpleasant industrial chemicals and is commonly found in toxic waste dumps.

Life has evolved to survive on earth in a remarkable range of environments. Nearly every ecological niche seems to be filled, although in many cases the rate of

metabolism is very low. But there are some exceptions. No organism has learned to extract the water it needs directly from ice: the ice sheets of Greenland are not green, in spite of ample sunlight. There are also no organisms that carry out their life cycles entirely in the air. Life (as we know it) requires liquid water and something substantial such as land or an ocean to make a home.

Life on Mars

Within our solar system, Mars is probably the other planet most likely to harbor life. This conclusion has nothing to do with the "canals" of Percival Lowell; the life we are discussing is microbial, not metazoan. Nor today do most scientists support the initial hypothesis put forward in 1996 that the Martian meteorite ALH 84001 contains fossil microbes (although the point is still debated). Rather, optimism about Mars derives from the fact that several billion years BP its climate was different. There is abundant geological evidence from spacecraft exploration that Mars once had a thicker atmosphere and liquid water on its surface.



The 1976 Viking landers carried instruments designed specifically to detect microbial life in the soil, but the results were negative. Although Mars has the most earth-like environment of any other planet in the solar system, the surface is too dry and too cold and too affected by solar ultraviolet radiation to meet the requirements for habitability. However, there is no reason to think that life could not have begun on Mars about 4 billion years BP, since earth and Mars apparently had similar surface conditions then. Future missions will include the return of samples, selected from sedimentary rocks at sites (such as ancient lake beds or hot springs) that once held water. The most powerful searches for Martian life (past or present) will thus be carried out in our laboratories here on earth.

Finding fossil life in ancient rocks would motivate an accelerated search for survivors. We will look for life that evolved to deal with the deteriorating climate of Mars, perhaps by finding some refuge that is warmer and wetter than most of the Martian surface. NASA's theme in searching for life is "follow the water". The most likely source of liquid water on Mars today is deep below the surface, where extensive aquifers may exist. Perhaps someday astronauts on Mars will drill deep wells down to this layer of liquid water and finally encounter living alien life.

One interesting twist on the search for life is derived from the presence of ALH 84001 and nearly 30 other Mars rocks that have been identified on earth. These are rocks blasted off the surface by meteorite impacts. Mars and earth are close enough together that they have exchanged material in this way throughout their history (although most of the traffic has been from Mars to earth, as a consequence of the lower surface gravity on Mars). It is possible that some of these rocks may have contained viable microorganisms. Mars might have seeded earth, or the two planets could have exchanged biological material. It is therefore conceivable that if we eventually find living things on Mars, they will be genetically similar to terrestrial life, for the good reason that they are our distant cousins. If so, it will be fascinating to study life that has evolved independently for close to 4 billion years, but we will be no closer to answering the fundamental question of how life began. The "holy grail" of astrobiology is not just to find life elsewhere, but to find and study life that had an independent origin from that on earth.

Life elsewhere in the solar system

Are there other locations in the solar system where there is liquid water? Recent studies of the satellites of the outer planets suggest positive answers, in spite of the cold surfaces of these worlds. In most cases, the putative liquid water is deep beneath the crust. The most tantalizing site, however, is Jupiter's satellite Europa. Data from the Galileo spacecraft (in orbit about Jupiter 1995–2003) on this Moon-sized world indicate the presence of a global ocean of liquid water beneath an ice crust only a few kilometers thick.

Life requires an energy source, and sunlight does not penetrate below the frozen crust of Europa. Life is therefore unlikely to have evolved photosynthesis there. But internal energy sources may be present in the Europan seas. To remain liquid, Europa's global ocean must be warmed by heat generated by tides and now escaping from the interior of Europa. Hot (or at least warm) springs might be active, analogous to those we have discovered in the deep oceans of the earth. Europa might therefore support life that derives its energy from the mineral-laden water in such springs.

Although some scientists think that Europa is the most likely place beyond the earth to find life in the solar system, others question whether life could originate in a dark ocean heated only by hot springs. Since we do not know exactly how life formed on earth, it is impossible to evaluate this possibility for Europa. One thing is clear, however: if there is life in the Europan oceans, it is likely to be unrelated to terrestrial life. There is no exchange of rocks between earth and Europa to provide the possibility of cross-contamination, as is the case for Mars. Thus Europa holds out the tantalizing prospect of a second genesis — an independent origin of life. If so, we can hardly guess what that life might be like. Will it be carbon-based? Will it utilize protein chemistry? Will it possesses a genetic material something like DNA or RNA? Or will it be more exotic than we can now imagine?

Habitable planets orbiting other stars

One of the most important recent developments in astronomy has been the detection of planets circling distant solar-type stars — with more than 100 such planets discovered by the end of 2002. These planets cannot be seen directly; they are detected by the "wobble" of their parent stars in response to the gravitational tug of the planets. So far, we can detect only giant planets (like Jupiter and Saturn), and such large planets (without solid surfaces) seem unlikely as the home of life. Further, many of the newly discovered giant planets are on eccentric

orbits or cluster close to their parent stars, where temperatures are far too high for liquid water. Still, their existence holds out the prospect of smaller worlds (either earth-like planets or satellites orbiting the giants) that might support liquid water and the other conditions necessary for biology.

In evaluating the prospect for life in distant planetary systems, astrobiologists have developed the idea of a habitable zone — a region around a star where suitable conditions might exist for life. Since the focus is on the presence of liquid water, the usual definition of a habitable zone is the range of distance from the star where water will be liquid on the surface of a terrestrial-type planet (that is, a planet with roughly the mass of the earth).

Obviously the earth is in the habitable zone for the solar system. Note, however, that earth's surface is above the freezing temperature of water only because the greenhouse effect in our atmosphere raises the average temperature by about 25°C. In the past, when the Sun was fainter, we were even more dependent on a greenhouse effect to maintain clement conditions. Thus, we must consider the nature of any atmosphere as well as the distance from the star in evaluating the range of habitability.

Our neighbor worlds provide some insight into the habitable zone within the solar system. Venus, the next planet closer to the Sun, has evolved through a runaway greenhouse effect into an oven where life is impossible, but it was once probably inside the habitable zone. Mars today is too cold and dry for surface life, but in the past it had a thicker atmosphere and apparently supported surface water (although perhaps its lakes and seas were ice-covered). Today Mars seems to be outside the habitable zone, but if the earth (with its greater ability to retain an atmosphere) were in the orbit of Mars, it might still be relatively warm. The current inhospitable nature of Mars is as much a consequence of its small mass as its distance from the Sun.

This is all very complicated, and scientists still differ in what they consider to be a habitable zone. Roughly speaking, however, the habitable zone in our solar system is limited to the terrestrial planets earth and Mars, and (perhaps early on) Venus.

THE SOUP OF LIFE?

The supposed shortcomings of the "Miller-Urey" experiments on the origin of life have provided ample fodder for many anti-evolutionary — and especially "intelligent design" — publications. Most of these, of course, focus on the version of these experiments presented in high-school or college texts and do not explore the primary research literature. Attacks like those by Jonathan Wells (for example, in *Icons of Evolution*) based on a very superficial treatment of the research may convince many people because they do not have access to the original literature.

Now, however, in a special article in the series Essays on Science and Society in the journal *Science*, Jeffrey Bada and Antonio Lazcano have provided a very readable and scientifically accurate overview of the whole field of origin-of-life research and the proper place of the contributions made by Miller's experiments. In addition to their very clear discussion of the history of origin-of-life research and the pivotal role that Miller's research played in its development, Bada and Lazcano explicitly take on a number of Wells's complaints. True to the style and approach taken by anti-evolutionists of all stripes, the ID crowd misleads the public into thinking that controversy about the specifics of Miller's model translates into doubt about a naturalistic explanation for the emergence of life on earth. Nothing could be further from the truth, of course.

Bada and Lazcano point out that Miller's model encouraged scientific research into the conditions and events that had been involved in the emergence of life on earth. Even if a number of his now 50-year-old experimental conditions prove to be inaccurate, they did, according to Bada and Lazcano, produce a vital area of research that has discovered much about the nature of early life and the conditions on earth — and elsewhere — that nurtured it.

Bada JL, Lazcano A. Prebiotic soup — Revisiting the Miller experiment. *Science* 2003 May 2; 300: 745–6. Also available on-line at <http://www.sciencemag.org/cgi/content/full/300/5620/745>.

[*See the review of* The Spark of Life: Darwin and the Primeval Soup *by Christopher Wills and Jeffrey Bada on p 47. Antonio Lazcano's "Did it all begin in a warm little pond?" will appear in the forthcoming revised edition of* Scientists Confront Creationism.]

BIOMARKERS

From the discussion above, our prime candidate worlds in the search for life beyond the solar system are terrestrial-type planets within the habitable zones of their stars. Astronomers are unable to detect such planets with current technology, but within a decade or so, space missions should allow us to determine how common such habitable planets are and to identify nearby candidate systems for further study. The NASA mission called Kepler, which is to be launched in 2007, is designed to determine the frequency of occurrence of terrestrial planets within the habitable zone of solar-type stars.

The fact that a planet is within the habitable zone does not ensure, of course, that it is actually inhabited. Indeed, one of the most important questions in astrobiology is just that: will life arise naturally when the environmental conditions are correct? It is thus important to consider how we might recognize the signature of life on a distant planet.

Even with the largest space-based telescope we can contemplate, we will never be able to obtain images of distant planets, as we do the worlds in our own solar system, let alone visit them with robot spacecraft. Astrobiologists therefore need a global biomarker — something distinctive to separate a live world from a dead one. To be detectable, these biomarkers should involve changes in atmospheric or surface chemistry that can only be the result of life.

If we observed earth from a great distance, and took sensitive visible-light and infrared spectra, we might just see such biomarkers. The most easily detectable evidence is the presence of abundant

free oxygen in the atmosphere, which produces distinctive features in near-infrared spectra. On earth, oxygen is the byproduct of photosynthesis; if life on earth should cease, the oxygen in the atmosphere would disappear within a few thousand years. The oxygen, therefore, is a biomarker. A similar atmospheric gas is methane, produced by microbes. Without the presence of life, methane would be quickly oxidized and disappear from the atmosphere. Probably the most distinctive biomarker for earth is the simultaneous presence of these two gases: oxygen and methane.

Unfortunately, for two billion years the earth was a living planet without the oxygen/methane biomarker in its atmosphere. Astrobiologists are therefore looking in more detail at the possible interactions between ancient microbial life and the atmosphere. One of the themes of astrobiology is to study the co-evolution of life and the planet. Our ability to detect the presence of life someday on an extrasolar planet depends on a better understanding of the complex interactions that could reveal the presence of a biosphere to our spectrometers.

Conclusions

The search for life is just beginning. It may require decades for a thorough exploration of Mars, and Europa is even less accessible. To search for biomarkers on distant earthlike planets requires not only that we discover such planets, but also that we construct enormous telescopes in orbit to measure the composition of their atmospheres in the search for biomarkers. A third possibility, of course, is that a successful SETI program will detect signals broadcast by a technical civilization somewhere in the galaxy. While this seems like a long shot, the rewards of success are certainly sufficient to motivate the search for such signals.

Astrobiology is a science that broadens our perspective on biology to include other worlds. It includes the study of evolutionary adaptations to extreme environments on earth, as well as the potential for life to develop on other planets. Because of its fusion of astronomy and biology (plus generous contributions from geology and chemistry), astrobiology has great public appeal. Dozens of books have been published in the past few years, and more recently astrobiology has found its way into college curricula, especially as a general education introduction to science. Two new textbooks have been published for such "Astrobiology 101" courses (*Life in the Universe* by Jeffrey Bennett, Seth Shostak, and Bruce Jakosky [San Francisco: Addison Wesley, 2003], and *The Search for Life in the Universe*, 3rd edition, by Donald Goldsmith and Tobias C Owen [Sausalito (CA): University Science Books, 2001]), and more than 100 college courses are currently offered (see <http://nai.arc.nasa.gov/institute/college_courses/>). Evolution, of course, lies at the heart of these studies — taken in the wide context of an evolving universe and of the coupled co-evolution of life with its host planet.

Astrobiologists are asking the big questions about the origin, evolution, and distribution of life in the universe. While it may be a long time before we get definitive answers to such questions, the quest for this knowledge is fascinating to educators and the public as well as the research community.

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Dextrous and Sinister Amino Acids

In a press release from the Skaggs Institute for Chemical Biology, part of the Scripps Research Institute, researchers announced a possible answer to one of the most vexing problems regarding the origin of life: why are so many bio-molecules "left-handed"? And how could the first bio-molecules have "chosen" only one type of handedness if molecules of both types of handedness are found in nature? Our bodies can only use the L-form of amino acids (left-handed) and the D-form of ribose molecules (right-handed). How did the very first biological molecules assemble out of a presumed mixture of right- and left-handed building blocks?

The press release describes work published in *Nature* by Scripps chemist M Reza Ghadiri, who has created a biological polymer that can discriminate between the two types of building blocks, taking those that are similar and building a copy of itself with them. Ghadiri's team constructed right- and left-handed peptide templates and mixed them with right- and left-handed versions of potential building blocks. In this study, the left-handed templates made more left-handed copies and the right-handed templates made more right-handed copies from the mixed building blocks, showing that the peptides favored the synthesis of correct duplicates, but the duplicates speeded up the reaction. They further discovered that if they added "mutant" peptide templates with a single incorrectly-handed molecule, these would correct the mistake and catalyze the formation of new molecules with the correct composition. The key to "handedness" in living things appears to be the early development of a polymer that selectively chooses and incorporates L-amino acids into living things.

Read the Scripps Institute press release at <http://www.scripps.edu/news/press/021401.html>; for the *Nature* article, see Saghatelian A, Yokobayashi Y, Soltani K, Ghadiri MR. A chiroselective peptide replicator. *Nature* 2001 Feb 15; 409: 797–801.

[*Thanks to Dave Thomas for this note.*]

Gas, Discharge, and the Discovery Institute

Andrew D Ellington and Matthew Levy, University of Texas at Austin

The following is an amalgam of the testimony provided by Andrew Ellington and Matthew Levy at the Texas State Board of Education hearing on September 10, 2003. The testimony was originally split into two segments because of time limitations on individual presentations. The combined version below is also more extensively referenced than the oral testimony.

I am Andrew Ellington, the Wilson M and Kathryn Fraser Research Professor in Biochemistry at the University of Texas at Austin. I have worked in the field of origins chemistry and biochemistry for over 20 years, and have published 165 peer-reviewed papers on this and related subjects. In this I am assisted by Matthew Levy, who has studied origins of life research for the past 8 years and who previously spent 3 years in the lab of Stanley L Miller, the namesake of the Miller-Urey experiment, at the University of California, San Diego. We therefore believe that we are qualified to speak on this subject.

We would initially like to point out that the primary purpose in having the Miller-Urey experiment in textbooks is to show that biological compounds can be generated by relatively simple prebiotic chemistry. This purpose is set forth in nearly every textbook. For example, in *Biology: Patterns and Processes of Life*, we find "… organic building blocks arose from simpler chemicals" (Raver 2004: 149). However, the criticisms leveled by the Discovery Institute's "Preliminary analysis of evolution in biology textbooks" (DI 2003) do not focus on this important fact. In other words, the arguments against the inclusion of the Miller-Urey experiment almost never talk about the meaning of the experiment itself.

In addition, though, the criticisms that have been advanced by the Discovery Institute are either completely wrong or misleading to the point of dishonesty. There are three prime examples of this, although others can also be found.

First, the Discovery Institute says that "When the Miller-Urey experiment is repeated with carbon dioxide (CO_2), nitrogen (N_2) and water vapor … no amino acids are produced" (DI 2003: 5).

This statement is false. It is factually incorrect. Amino acids are produced when the Miller-Urey experiment is run with only carbon dioxide, nitrogen, and water vapor. This was shown in a classic paper by Schlesinger and Miller (1983a). The evidence is indisputable, and has never been contradicted.

Why is this information, which is readily available in the scientific literature, not cited by the Discovery Institute? Jonathan Wells often cites a chapter of a book by Heinrich Holland of Harvard University that purports to prove their claims (Holland 1984). To quote Wells, "In 1984, Heinrich Holland confirmed that mixtures of carbon dioxide, nitrogen and water vapor yield no amino acids at all" (Wells 2002). In fact, the Holland chapter cited by Wells was a review. The primary literature referenced in that chapter does not support Wells's claims. Neither of the primary references (Khare and others 1981; Kawamoto and Akaboshi 1982) specifically looks for amino acids, as opposed to Schlesinger and Miller's work. I have talked with Holland, and he says he was unaware of Miller's 1983 work when he submitted the chapter. These facts can be readily discovered by anyone with scientific training, and yet the Discovery Institute has chosen to mislead you and the citizens of Texas.

As we have said, the Miller-Urey experiment showed exactly what it was supposed to, and exactly what the textbooks say it does: that biologically relevant compounds can be generated by relatively simple prebiotic chemistries.

Second, the Discovery Institute suggests that reducing gases would not have been present on the early earth (Wells 2002; DI 2003: 19, 26).

This statement is also false. It is factually incorrect. Current theories support a mildly reducing atmosphere on the early earth (as reported by Kasting 1993, a review that has again been incorrectly used by the Discovery Institute). Moreover, even if the overall atmosphere was neutral, there would have been multiple sites on the earth's surface that were locally reducing. For example, reduced gases such as hydrogen are expelled around sites of volcanic activity (Holland 1984; Kasting 1993; Delano 2001). Thus, at many locales on the early earth, electric discharges precisely like those shown in the Miller-Urey apparatus would have produced amino acids and other organics.

Once again, the Miller-Urey experiment showed exactly what

it was supposed to, and exactly what the textbooks say it does: that biologically relevant compounds can be generated by relatively simple prebiotic chemistries.

Third, the Discovery Institute claims that under these conditions, "… the molecules produced include toxic chemicals such as cyanide and formaldehyde but not amino acids" (DI 2003: 15, 35).

This again is not true. It is factually incorrect. Amino acids as well as other organic compounds have been shown to be produced (Kawamoto and Akaboshi 1982; Schlesinger and Miller 1983a, 1983b; Hanic and others 2000). Moreover, the so-called toxic chemicals cyanide and formaldehyde are actually prerequisites for the formation of important biochemical compounds, such as amino acids (Abelson 1966; Miller 1986), nucleotides (Oró 1960), and sugars (Miller and Orgel 1972). That is, these compounds are expected to be present because they are the building blocks for important biomolecules. Labeling these compounds as "toxic" is extremely misleading and has nothing to do with their role as important prebiotic chemicals.

Scientists are supposed to be impartial, judging evidence on its merits. However, having read the inaccurate treatment of the data submitted by the Discovery Institute, we can only conclude that their testimony with regard to the Miller-Urey experiment is based solely on bias rather than on the hard scientific evidence that is readily available and accurately reported in each textbook.

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Early Life and Ultraviolet Light

The genetic damage caused by ultraviolet (UV) radiation is so well known that researchers have generally considered the high levels of this radiation falling on the young earth to be a serious hurdle for the emergence and establishment of early life. However, in a recent article in the journal *BMC Evolutionary Biology*, Armen Mulkidjanian and colleagues suggest that the ability of DNA to absorb UV radiation may have been the key to establishing life on earth — leading later to the production of a protective ozone layer to screen living things from the destructive potential of UV radiation. Using computer models, these researchers examined the ability of the nitrogenous bases in nucleic acids to absorb UV radiation and protect the sugar–phosphate backbone from damage. They found that RNA molecules were more stable under such bombardment than other long-chain molecules. In essence, they argue that nucleic acids were selected *for* in an environment that was high in UV radiation because these molecules were more resistant to the damaging effects of the radiation than other compounds.

Mulkidjanian AY, Cherepanov DA, Galperin MY. Survival of the fittest before the beginning of life: Selection of the first oligonucleotide-like polymers by UV light. *BMC Evolutionary Biology* 2003 May 28. Available on-line via <http://www.biomedcentral.com/bmcevolbiol>.

[*Prepared from a news release at* BioMed Central *available on-line via <http://www.biomedcentral.com/bmcevolbiol>.*]

"Intelligent Design": Illusions of an Informed Public

George Bishop, University of Cincinnati

Despite a pile of evidence showing the American public to be inattentive and uninformed about many aspects of public affairs, national and regional polls frequently fail to screen out respondents who know little or nothing about the subjects of the questions they ask. Not only that, polling organizations often encourage respondents to answer such questions by presuming they are familiar with the topic. Survey questions of this kind typically begin by saying to the respondent: "As you may know …", or by providing some other informative preamble.

Pollsters generally defend these practices by saying that it is just a way to find out how respondents would think about the issue or topic if they did know more about it. But such practices can result in illusions of an informed public that seriously mislead the policymaking powers that be.

Recent public opinion polls in Ohio on the issue of "intelligent design" illustrate just how misleading such findings can be. The idea that an intelligent designer or some supernatural force created the universe and guided the development of human life has become the center of a heated controversy among Ohio citizens.

For the past year or so, the State Board of Education in Ohio has wrestled with the policy issue of whether to teach "intelligent design" in public school science classes as an alternative to the scientific theory of evolution. Just recently, according to an Associated Press story of October 15, 2002, a committee of the Ohio Board recommended "… that science classes in the state emphasize both evolution and the debate over its validity … and left it up to individual school districts to decide whether to include in the debate the concept of 'intelligent design' …."

As far as most college and university science professors in Ohio are concerned, however, the concept of "intelligent design" does not have a shred of scientific evidence to support it and is essentially a religious view that does not belong in the science curriculum of the public schools. Despite this *expert* opinion, "public opinion" polls on the issue have played an important role in telling the powers that be that a seemingly informed public wanted them to do otherwise.

Consider some of the headlines and news stories about public opinion produced by the polls on the "intelligent design" issue:

"*Ohioans Don't Want Evolution Only*." In an article for the *Columbus Dispatch* (May 10, 2003), Catherine Candisky cited a poll conducted by Zogby International for an "intelligent design" advocacy group, the Discovery Institute, claiming "… nearly two-thirds of Ohioans support instruction about both Darwin's theory of evolution and any scientific evidence against it."

"*A majority of those surveyed want evolution, intelligent design to get equal time in schools*." Writing in the *Cleveland Plain Dealer* (June 9, 2002), Scott Stephens and John Mangels reported the results of a statewide poll commissioned by the *Plain Dealer* and conducted by Mason-Dixon, a Washington-based polling organization. It showed that "A clear majority of the state's residents — 59% — favor teaching evolution in tandem with 'intelligent design' in public school science classes…"

"*Ohioans: Teach Darwin, Design*." Picking up on the drumbeat of the *Plain Dealer* poll, the Associated Press (June 2002) told Ohio and the rest of the world that, "A majority of Ohioans want public schools to teach evolution and a concept called 'intelligent design' when they discuss how life originated and changed…"

For better and for worse these headlines and news accounts became the *reality* of public opinion for the Ohio Board of Education, editorial writers, various pundits, and, of course, the politicians. To the contrary, I would contend that public opinion on the "intelligent design" issue, as it was presented in the press, was mostly an illusion produced wittingly or unwittingly by those who commissioned and conducted the polls.

Consider the following piece of evidence from an Ohio Poll conducted by the Institute for Policy Research at the University of Cincinnati this past September. A statewide sample of Ohioans was asked, "Do you happen to know anything about the concept of 'intelligent design'?"

Despite the significant coverage, editorials, and polls on the intelligent design issue presented in Ohio's news media for several months, the vast majority of Ohioans (84%) said no; they knew little or nothing about it. Only 14% said yes (and who knows what they actually knew?) and the rest (2%) were not sure. In other words, the great majority of Ohioans did not know enough about the concept of "intelligent design" to have formed an opinion.

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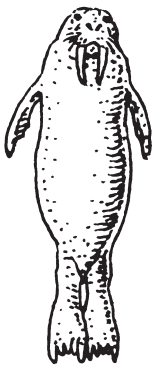

The vast majority of Ohioans probably also knows little or nothing about the nature of scientific evidence or what a scientific theory of evolution actually means. And yet they appeared to be quite informed about this policy issue, according to the polls conducted by Zogby for the Discovery Institute — an advocacy organization for the "intelligent design" movement based in Seattle — and by Mason-Dixon for the *Plain Dealer*. How was this false and misleading impression created? In one instance it was done with leading questions; in the other, by "educating" the respondents.

The poll conducted by Zogby for the Discovery Institute last May offers a classic example of how to bring a respondent to a desired conclusion. Like many other advocacy polls, the Zogby poll generated the false impression of an informed and opinionated public by first educating respondents about the issue and then asking them whether they had an opinion on it.

In fact, the pool did not even ask respondents whether they had heard or read anything about the "intelligent design" controversy, but instead informed them in a seemingly even-handed manner — the standard "fairness" tactic of "intelligent design" advocates — that "The Ohio State Board of Education is currently trying to decide whether high school students should learn *both* the evidence *for* and *against* Darwin's theory of evolution" (my emphasis).

They were then asked, "Regarding teaching the theory of evolution, which of the following two statements comes closer to your own opinion — A. Biology teachers should teach only Darwin's theory of evolution and the scientific evidence that supports it, [or] B. Biology teachers should teach Darwin's theory of evolution, but also the scientific evidence against it."

Not surprisingly, nearly two-thirds of Ohioans (65%) picked alternative B, not because they understood anything about scientific evidence, rival scientific theories, or the policy implications of their answers for the controversial decision facing the State Board of Education, but most likely because they endorsed the democratic, fairminded idea of presenting evidence for and against any theory. After all, there are two sides to every issue.

Having gotten them to express an opinion with the general "fairness" framing of the issue, the Zogby poll then led respondents to the psychological implications of their answer by asking them, "Do you strongly agree, somewhat agree, somewhat disagree, or strongly disagree with the following statement: when Darwin's theory of evolution is taught in school, students should also *be able to learn* about scientific evidence that points to an *intelligent design* of life?" (my emphasis).

Even though most respondents had probably never heard or read a thing about the concept of "intelligent design", by a margin of more than 6:1 they were more likely to agree (78%) than disagree (13%) with this apparently evenhanded proposition, with just 9% saying they were not sure. Ergo, the *Columbus Dispatch* headline, "Ohioans Don't Want Evolution Only" represented what appeared to be an example of a well-formed "public opinion" on a controversial issue confronting the State Board of Education.

Nor was this the only example of seemingly well-informed public opinion on the "intelligent design" issue. Just several weeks later a statewide poll on the topic of evolution and "intelligent design" commissioned by the *Plain Dealer* and conducted by Mason-Dixon gave exactly the same impression of a decided majority. Though better designed, free of advocacy, and much more comprehensive than those in the Zogby poll, the questions asked in the *Plain Dealer* survey (which was also the basis for the Associated Press story) created the same misleading impression of an informed public that understood the complexities of the "intelligent design" issue and had formed an opinion on it.

But when asked how familiar they were with the concept of "intelligent design", only 18% said they were very familiar with the idea; 37% indicated they were just somewhat familiar with it; and 45% admitted they were not that familiar at all with the notion.

Regardless of how familiar they were with the idea of "intelligent design", the *Plain Dealer* poll educated respondents as to what it was about in a follow-up question and then asked them to pass judgment on its validity: "The concept of 'intelligent design' is that life is too complex to have developed by chance, and a purposeful being or force is guiding the development of life. Which of the following best describes your view of 'intelligent design'…?"

About a fourth (23%) considered it a completely valid account of how humans were developed; nearly half (48%) regarded it as a somewhat valid account; and just 22% thought it was not a valid account. The rest said they were not sure. But what could the public's understanding of *validity* possibly mean?

Furthermore, as reporters Stephens and Mangels made clear in their *Plain Dealer* analysis of the poll, the great majority of respondents understood the religious undertones of the question about "a purposeful being or force that is guiding the development of life": "Two-thirds of the poll respondents", they wrote, "believe the unspecified 'designer' in 'intelligent design' really is God. In fact, that's part of the attraction."

For many respondents, then, the question on "intelligent design" got interpreted not so much as a question about how human life actually developed, but rather as a test of whether they believed in God, making it much easier for them to generate an opinion on the concept of "intelligent design".

Having brought the respondents up to intellectual speed with prior explanations of "intelligent design" and questions about God's role in the development of life on earth, the poll then got to the heart of the "equal time" issue by asking them the following question:

> Currently, the Ohio Board of Education is debating new academic standards for public school science classes, including what to teach about the development of life on earth. Which position do you support — teach only evolution, teach only "intelligent design", teach both,

teach the evidence both for and against evolution, but not necessarily "intelligent design", or teach nothing about human development?

Given the fairness framing of the issue, it is not surprising that a sizable majority (59%) of those polled favored the evenhanded position of "teach both". The *Plain Dealer* could now characterize public opinion in Ohio on the issue as decisive: "A majority of those surveyed want evolution, intelligent design to get equal time in school." Case closed.

Far from an isolated example, the sort of illusion of public opinion generated by the Zogby and *Plain Dealer* polls on the issue of intelligent design represents an all too common occurrence in contemporary survey research. As I have argued elsewhere, such illusions have become more ubiquitous than ever, not only because of the proliferation of "pseudo-polls" in the mass media that give the false impression of a public which has opinions on nearly every topic under the sun, but also because of chronic problems in the practice of asking survey questions: widespread public ignorance of public affairs, the inherent vagueness of the language used in most survey questions, and the unpredictable influence of variations in question form, wording, and context.

The danger in all this, of course, is that because there is typically no peer review of such "direct to the media" polls, nor any sort of journalistic gate keeping, virtually no one can tell the difference between good quality work and biased and misleading results once the poll results are released to the public.

The prestige of the polling organization releasing the results and the statistical percentages, accompanied by the usual reassuring scientific statement about sampling error, give the impression that it is all just as reality-based as a standard pre-election poll. Unlike pre-election polls, however, there is no Wednesday morning reality check with behavioral evidence. The result is a misled and unprotected public.

Many pollsters may, of course, prefer to continue business as usual, manufacturing opinions with lead-in phrases like, "As you may know …", and other preambles that educate the respondent. If, on the other hand, they were to use filter questions on a regular basis to screen out the less well informed, it would probably not make good copy to report, again and again, that large numbers of citizens, and in some cases majorities, have no opinions on issues of everyday discourse in elite political, journalistic, and academic circles.

But I think we do the public and the powers that be a great disservice by continuing to manufacture artificial and illusory portraits of an informed public opinion on issues like "intelligent design", when we could do so much better. In the case of "intelligent design" the power of the pollsters did a great disservice to the scientific community as well.

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Zogby's Polling Assailed

In "John Zogby's creative polls" (*The American Prospect* 2003 Feb; available on-line at <http://www.prospect.org/print/V14/1/mooney-c.html>), Chris Mooney criticizes Zogby International, a polling firm founded in 1984, for relying "on creative phrasing to give the impression of wide public support for the view that the given client is promoting." Prominent among his examples was the national poll conducted by Zogby for the Discovery Institute in August 2001, which asked, "Do you strongly agree, somewhat agree, somewhat disagree, or strongly disagree with the following statement: 'When Darwin's theory of evolution is taught in schools, students should also be able to learn about scientific evidence that points to an intelligent design of life.'" Mooney comments, "At first glance this might seem innocuous enough — who could oppose the teaching of *scientific* evidence? But how many respondents grasped that 'intelligent design of life' is used as a synonym for divine creation? Also, as Eugenie C Scott of the National Center for Science Education points out, the premise that scientific evidence supporting ID actually exists is a highly dubious one."

The president of the Discovery Institute, Bruce Chapman, wrote to *The American Prospect* (2003 Apr; not available on-line) to complain, contending that (1) the Zogby poll on evolution was not about "intelligent design" but about whether "the scientific evidence against as well as for Charles Darwin's theory" ought to be taught, (2) Mooney used a definition of "intelligent design" employed by "its most ardent opponents (for example, Eugenie Scott of the 'Darwinist' lobbying group [t]he National Center for Science Education)", and (3) Mooney ignored the fact that the two polls in Ohio (conducted by Zogby for the Discovery Institute and by Mason-Dixon for the *Cleveland Plain Dealer*) produced similar results. Mooney replied by noting that (1) the phrase "intelligent design" occurs "pretty front and center" in the Zogby poll, (2) his characterization of "intelligent design" accords with that of the American Association for the Advancement of Science, wryly adding that "Readers can decide for themselves whether to trust the nation's premier scientific organization or [t]he Discovery Institute", and (3) the two polls in Ohio were flawed in exactly the same way that the national Zogby poll was, so it is unsurprising that their results were similar.

Faith, the Environment, and Evolution: An Interview with John F Haught

John F "Jack" Haught is Landegger Distinguished Professor of Theology at Georgetown University in Washington DC and director of the Georgetown Center for the Study of Science and Religion. His area of specialization is systematic theology, with a particular interest in issues pertaining to science, cosmology, ecology, and religion. He is the author of several books, including Science and Religion: From Conflict to Conversation. God After Darwin: A Theology of Evolution, *and* Responses to 101 Questions on God and Evolution *(reviewed by Phina Borgeson on p 52); his newest book,* Deeper than Darwin: Evolution and the Question of God, *was published in 2003 by Westview Press.*

Haught visited the University of California, Davis, on March 18 and 19, 2002, to deliver the annual St Augustine Chair Lecture of The Belfry campus ministry, which was concomitantly was the keynote address of a conference on Care for God's Creation: Spirituality and Environmental Stewardship. NCSE Faith Network Project Director Phina Borgeson attended and interviewed Haught afterward.

RNCSE: The organizers of the Care for God's Creation event wisely, in my opinion, asked you to speak on evolution as an important foundation for any faith-based environmental activism. It has seemed to me that there are similarities between people who deny evolution because of their beliefs and those who disparage environmentalism out of faith. What would you say is the theological common ground between those two groups?

HAUGHT: Well, first, they are both dualistic in their thinking; it is their view of reality that we humans are essentially spiritual beings only accidentally imprisoned in a material universe. Second, and perhaps most important, it is their view of ultimate destiny that militates against their taking the environment seriously. I grew up in the country, on a family farm in rural Virginia. There is a radio program I listen to on Sunday afternoons that plays the kind of music common in that area, "Stained Glass Bluegrass". I still have an affection for the music, but not for the theology, which says that our ultimate home is elsewhere: earth is like a school for souls, and when it is all over, we will be harvested away from earth to heaven. To such a mindset, taking care of this planet seems pointless. And even if those who espouse these beliefs accept evolution, they are not interested in doing anything with it theologically. The environment is not important when the destiny of the individual is deemed significant and the destiny of all of creation is not. Those of us doing theology after Darwin, though, can speak with even more certainty about the inseparability of cosmic and human destiny.

RNCSE: What about parallels between the two in activism and methods?

HAUGHT: The detractors project onto both evolution and environmentalism their own sense of what they have been taught is evil. Basically, evolution is seen as evil and the avenue by which modernity has allowed in all kinds of ills. For many who would deny it, the word "evolution" is so symbolically charged that of itself, it arouses a moral impulse toward activism.

Evolution, of course, is change over time. Evolution's detractors have a concept of God and a concept of order according to which change is considered demonic or even satanic. And they have a lot of conservative money to fight change.

They do not want perfection in Whitehead's sense, which includes both novelty and order. they want it in a trivial form devoid of novelty. For Whitehead, perfection is not attainable, but a goal, the highest possible integration of novelty and order (which he also called beauty). Too much novelty is chaos; too much order is banality.

Creationists and those who reject environmentalism also cannot distinguish between a sacramental outlook, in which nature is symbolic or revelatory of God, and pantheism, in which nature is equated with God. There does seem to be less creationism in sacramental churches, but there is a growing "intelligent design" movement in Catholicism.

RNCSE: Of course — Michael Behe is a Roman Catholic, and the University of San Francisco, a Jesuit institution, hosted the 2002 IDEA conference.

In your lecture, you talked about how any Christian theology must be related to the revelation of God in the person of Jesus. You identified three key attributes of Jesus: humility, self-gift, and opening up of the future, or promise. It seemed to me that each of these runs counter to the theology implicit in "intelligent design".

For example, when talking about God's self-gift, you said,

"Revelation is not the passing of information from heaven to earth, but the infinite entering the finite world." This seemed to allude to the theological uses, or misuses, of information in the work of Phillip Johnson and William A Dembski. Would you care to comment?

HAUGHT: Well, that view is based on Karl Rahner's theology, especially his thinking that revelation is at root the mystery of God pouring itself without reservation into the creation. I have an intuition that if you look upon nature simply as design, it tends to freeze out the novelty that brings life. Dawkins said that design is "brittle". But there are always new forms of order pouring in from the infinite. Because the fullness of divine infinity cannot be received all at once by the finite cosmos, something new is always coming into the universe. The rigidity of design is a barrier to the self-gift of the divine. Good evidence for this is that we see no perfect adaptations.

RNCSE: Of opening up the future, you said, "The universe is seeded with promise rather than design." Your comments?

HAUGHT: Theologically, promise is a field of endless possibilities. Jürgen Moltmann (a contemporary German theologian, influential, among other things, in the renewal of interest in eschatology among liberal Protestants and in propounding a theology of hope) has developed some interesting ideas here. He reminded us that in the biblical view of things, the word "God" means "Future". Possibilities are more powerful than actualities. Possibilities can become actual, but the actual can no longer become possible. The conception of God as the Designer is just too hard and dead to capture the rich way God relates to nature, drawing us into the future in a Teilhardian way.

RNCSE: What about humility? Is there a way you would contrast your understanding of that with the theology of the "intelligent design" crowd?

HAUGHT: It seems to me that fear drives people toward design: fear of change, of novelty, of the infinite. "Intelligent design" puts a sacred canopy over their lives. But design does not truly conquer fear. Design is about a God of power and might rather than a God who shares in our sufferings. Like most natural theology, "intelligent design" fails to make room for the cross. Yet it is a trust in the self-emptying Jesus in passion and crucifixion that drives out fear.

RNCSE: I know that you are aware of the efforts to insert "intelligent design" into the science education standards in Ohio. What would you say to clergy and other religious leaders there who want to oppose "intelligent design" from a theological perspective?

HAUGHT: Well, before I say anything about theology, let me say that from the point of view of science, it is just plain inappropriate. Appeals to "intelligent design", for example Michael Behe's "irreducible complexity", are theological diversions, not scientifically fruitful suppositions.

Theologically, "intelligent design" trivializes both science and the scriptures by bringing in God at the level of science. It has religion moonlit in an explanatory slot that belongs to science.

Proponents of "intelligent design" and of evolutionary materialism agree that there is one explanatory slot — so we need to fit God into the slot or he will not be present at all. If there is only one slot, there is going to be conflict. In contrast, in my new book *Deeper than Darwin,* I argue for explanatory pluralism, on which such a conflict need not arise.

The proponents of "intelligent design" seem unable to separate evolution from evolutionary materialism. They throw the baby out with bath water, discarding good science, and at the same time turning God into a tinkerer rather than a creator.

RNCSE: How did you get into this anyway?

HAUGHT: Well, when I was in Catholic seminary, I got into reading Teilhard de Chardin, whose work struck a chord with my cosmic romantic sense. I have also delighted in Whitehead and his romantic reaction to the dominant philosophy of his place and time. I find that *Science and the Modern World* is still the most influential book I have read, and the best critique of scientism. I think Whitehead was the first post-modernist.

When I left the seminary, I worked in systematic theology, with no idea of going into science and religion as a field. But when I arrived at Georgetown more than thirty years ago, I realized that there was no course to help students to integrate what they were learning in science with what they were learning in the humanities. I like to think that my present work on evolution and theology is helping people — not just my students — undertake a religious voyage of discovery that respects both classical spirituality and the evolutionary discoveries of modern science.

Searching for the Last Common Ancestor

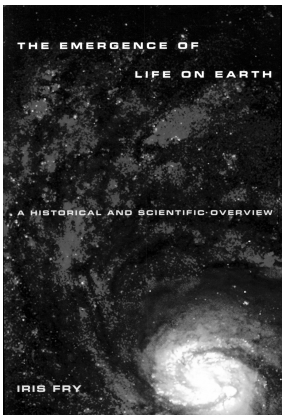
A review in the journal *Molecular Microbiology* discusses the emergence of the 3 domains of organisms — Bacteria, Archaea, and Eukarya — and current research into the nature of the last common ancestor for these lineages. This review explores the role of horizontal gene transfer in the context of other mechanisms for differentiating early life into the cell types that distinguish the 3 domains.

Glansdorff N. About the last common ancestor, the universal life-tree and lateral gene transfer: A reappraisal. *Molecular Microbiology* 2000; 38 (2): 177–85.

For the abstract, see <http://www.blackwell-synergy.com/journals/processfree2.asp?contentid=mmi%2E2000%2E20&filetype=abstracts&article=75199>.

[*Thanks to David Ussery for bringing this article to our attention.*]

BOOKREVIEWS



The Emergence of Life on Earth: A Historical and Scientific Overview

by Iris Fry
New Brunswick (NJ): Rutgers University Press, 2000. 327 pages.

Reviewed by Paul R Gross, University of Virginia

In 1997, Iris Fry, a historian and philosopher of science working in Israel, published in Hebrew *The Origin of Life: Mystery or Scientific Problem?* There were good reports of this work, but the fraction of all its potential readers who are competent in Hebrew is small. That difficulty is now circumvented: Rutgers University Press has produced a handsome, expanded version based upon the original volume, but now in English and in paperback.

The author undertook to cover a dauntingly broad range of the issues — scientific and otherwise — surrounding the origin of life *and* its scientific study. This is not to imply that there is such a thing as non-scientific *study* of the origin of life, but there certainly are a great many influential, passionately-held, non-scientific convictions on the subject. Many of those are actively hostile or arrogantly dismissive toward the science. In fact, there was no "study", no objective inquiry, of the origin of life until very recently. Through most of human history we all *knew* either that (a) it arises spontaneously, all the time, as in dirty rags, or (b) it was or is created in an act of will on the part of gods or other super-agents. Only post-Darwin and post-Pasteur have the origin of life and the extraterrestrial prevalence-of-life arisen as honest questions. As a formal research discipline, the origin of life is an infant aged 50. It already has, however, a good list of heroes, skirmishes, defeats, and victories.

The long, full history, then, must be a part of any attempted *general* treatment of the state of the science. It is done in the opening chapters, like the rest of this book, fairly and conscientiously. The recent science, however, has its own, complex history. Some knowledge of that internal history is indispensable to an appreciation of achievements and the prospects for answers. We do not yet know how life came to exist on earth, or whether there is something like it elsewhere in the universe — although the chances for a plausible answer to the first seem very good now, and the likelihood of the second is high and getting higher with every discovery of an extrasolar planetary system.

One of two virtues of Fry's account is that it makes a sympathetic understanding of the current science possible by taking up, systematically and seriatim, the major schools of recent and contemporary thought. It locates them in time and with relation to the adjacent sciences of life, geophysics, and astronomy. The other virtue is that the science is presented competently and without superficial glosses. There is sufficient detail and more than adequate bibliography, so that a general reader with some science background has a chance to judge the quality of competing theories and the strong arguments stirring the field. Those have to do with primitive earth atmospheres and abiogenesis of organic compounds, the possible deposit of same by incoming cometary and other extraterrestrial debris, a metabolism-first or a gene-first pre-biotic chemical evolution, an RNA-first world or a proteinoid-coacervate world or a solid-state catalytic world, panspermia or all the way up from low-molecular-weight monomers right here on planet earth.

There are then, necessarily in so broad a review as this of the state of inquiry, the two questions most recently mooted. First, with the help of creationist venture capital, is the new-style "intelligent design" argument — William Paley resurgent — and its political movement. The second is the possibility — defended and attacked with increasing heat these last five years — of a former if not a current microbial life on Mars. These issues close the book: there has been, so far as I know, no other readable account of these arguments in the specific context of scientific research on the origin of life.

Iris Fry's effort succeeds. It is not a simple matter to set forth, even in general terms, and then to compare (for example) the metabolism-centered origins hypotheses of Dyson, Kauffman, Wächterhäuser, and Morowitz, but Fry does it, respectfully and with justice to each. The book deserves to be read. And, although the Modern Synthesis of evolutionary biology is intellectually independent of how life on earth arose, or even of how we define "life", this literate recounting of the research effort to find out must be useful to every student of evolution.

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[*Reprinted with permission from* Human Nature Review *2002; 2: 365–6.*]

The Spark of Life: Darwin and the Primeval Soup

by Christopher Wills and Jeffrey Bada
Cambridge (MA): Perseus Publishing, 2000. 320 pages.

Reviewed by Andrew Pohorille, NASA

Questions about the beginnings of life have always fascinated humans in ways that transcend time and culture. For most of our history, they were within the realms of philosophy and religion; they have truly become a part of mainstream natural science only in the last half-century. Not surprisingly, scientists have tried to capture this interest in our distant origins and have presented their views on the subject in a number of books aimed at a wide audience. Some of these books make interesting reading but rarely attempt to present a complete, unbiased, and well-informed picture of the origins and early evolution of life. Instead, they usually serve to forward the author's pet theory. Some authors ponder a philosophically fascinating, but possibly undecidable, question whether we came into existence by chance or necessity. Others throw their hands in the air and exclaim, "it's a miracle!" In the latest entry on this subject, entitled *The Spark of Life*, authors Christopher Wills and Jeffrey Bada do not seem to have an agenda. They attempt to lay things out as we know them today and they do a pretty good job of it.

The book follows a simple and logical layout. It starts with a discussion of the chemical evolution that led to the formation of the building blocks of the simplest living systems and proceeds to a description of the origins of the solar system and the conditions that determined the chemistry on the early earth. Using this knowledge as a constraint, the authors present different theories on how organic molecules self-organized into cell-like structures and how these structures evolved to form animate matter. In the process, they touch on such fascinating topics as the origin of the genetic code and energy-utilizing systems. The next two chapters are devoted to the early evolution of life and different attempts to reconstruct the tree of life that captures evolutionary relationships between different organisms. The focus on life in extreme environments is a good introduction to the last chapter, in which different possibilities of life beyond the earth are discussed.

In the limited space, Wills and Bada nicely capture most of relevant, contemporary research and on many occasions present several competing points of view. Sometimes they indicate their preference for a specific hypothesis, whereas in other cases they refrain from judgment. On a few occasions, they bend over backwards not to take sides in disputes between different schools of thought, for example, "the RNA world" versus "metabolism first" concepts of the origin of life. I like this caution and objectivity; being cautious is particularly wise now because in the next decade revolutionary developments in biological sciences may dramatically change our understanding of the earliest biological systems.

Not all is rosy with the book, however. The authors aim to present all biological processes relevant to early life in Darwinian terms. This has been, with perhaps a few modifications, the canonical view of evolution for quite some time. The novel aspect in this book is supposed to be an attempt to extend the Darwinian picture backwards in time to the origin of life. Wills and Bada correctly point out that Oparin was reduced to handwaving at this point. They claim that they can do better. The relevant question, however, is whether they do better than what we currently know. Unfortunately, I am afraid that they do not. Whenever they outline their vision of protobiologic evolution (for example, see p 121–2), they also use a lot of hand-waving in a way that does not advance our understanding of the problem in any significant way. They could have done a much better job had they emphasized the physical and chemical principles that lead to self-organization of matter.

These principles are far more central to our understanding of the emergence of life than the specific inventory of organic molecules available for this process. Yet the discussion of these principles is, at best, superficial. Wills and Bada briefly discuss the work of Dyson and Lancet and dispense with it with a flip comment: "Lancet has, however, not yet attempted to persuade molecules in the real world to undergo the same spontaneous organization that his imaginary molecules undergo in the computer" (p 138). They should have known better: the purpose of Lancet's and other similar studies is not to simulate organic chemistry on the computer but to elucidate the poorly understood rules that lead to the organization of chemical reactions into pathways capable of evolving to higher complexity. The authors paid equally little attention to molecular theories of self-organization. They could have explained "sorting out the gemisch" much better by introducing the concept of hydrophobic effects, which provides a unified framework for understanding such diverse phenomena as phase separation, formation of vesicles, folding of proteins, and spatial segregation of cellular components.

Another weak point of this book is its illustrations. Some figures and diagrams are of poor quality; others are not very informative. In some other instances, figures would have been helpful but are not provided. I do not care very much for the

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Pseudoastronomy Debunked On-Line

A new annotated guide listing over 200 skeptical resources about astronomy, UFOs, moon hoaxes, faces on the planets, crop circles, and other examples of astronomical pseudoscience is now available on the web site of the Astronomical Society of the Pacific at <http://www.astrosociety.org/education/resources/pseudobib.html>.

color plates included in the book (with a single exception of David Deamer's vesicles). I especially dislike the artist's renditions of various events on the early earth. This is both bad art and bad science.

A nice touch was to recall the historical record of studies relevant to the origin of life by retracing critical steps and missteps on the path to our current understanding of the subject, dating back to the 17th century. One interesting lesson from this historical overview is that some theories considered certain at one point were proven wrong a little later. The authors illustrate this point with several examples in the first chapter and then fall victim to the same trap shortly afterwards. They start chapter 3 by stating that William Schopf unequivocally demonstrated that organisms lived on the earth 3.5 billion years ago. However, recent work by Brasier and others (*Nature* 2002; 416, 76–81) puts this assertion in question.

The book is clearly aimed at a broad audience. It requires no more than a basic, high-school–level knowledge of the natural sciences, and therefore it can be easily read by college students and lay persons interested in the origin of life. Since the book satisfactorily explains most contemporary views on different aspects of the problem, it would also be also good reading for high school and college educators who want to refresh their knowledge of the field. It is written in a light and lively manner. One does not have to read it in full concentration in the hushed atmosphere of a library. It can be read equally well on a plane, in bed, or on a beach while sipping a cold drink. For those who want to spend a day learning about the origin and early evolution of life, *The Spark of Life* is probably the best choice. For those who want to get a little deeper into the subject, I suggest that they start with this book and then, equipped with the current knowledge acquired from the book, critically read intellectually more stimulating but also more biased books by Jacques Monod, Paul Davies, Freeman Dyson, and others.

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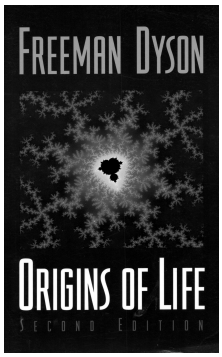

Origins of Life

by Freeman Dyson
New York: Cambridge University Press, 1999 (second edition).
100 pages.

Reviewed by Danny Yee

Origins of Life presents an alternative to RNA world theories for the origin of life. It argues for a "dual origin". In this view, protocells began as protein-based systems geared to the production of more proteins; however, the "reproductive" process produced only a few entities that were accurate replications of the original. Later these cells were "infected" by parasitic nucleic acids. In putting metabolism before replication, Dyson follows in the footsteps of Oparin, who proposed a similar "enzymes before genes" approach back in 1924; other avowed inspirations include Schrödinger, von Neumann, Eigen, Orgel, Margulis, and Kimura.

Dyson constructs a "toy" model, a system of recombining monomers in which "alive" and "dead" can be defined. With plausible parameters for numbers and types of monomers and catalytic efficiency, the jump to an organized state can happen with reasonable probability through random drift; Darwinian selection then drives the system towards greater complexity. He goes on to look at the questions his model raises and its broader biological and philosophical ramifications. It is important to keep in mind, as Dyson himself stresses, that his model is a "toy" — an abstraction designed to suggest experiments and more complex modeling.

A theoretical physicist venturing into biology, Dyson avoids the obvious pitfalls: he is suitably humble, even self-deprecating in places ("this philosophical hot air"), and he offers useful insights from a physicist's perspective without getting carried away either by his own pet ideas or by metaphorical applications of physics to biology. At the same time he makes strong arguments with real substance, going beyond the level of most popular science writing. (The text assumes the reader has knowledge of basic biochemistry and cell biology along with a bit of simple mathematics for the model itself.) Most impressive of all, Dyson writes succinctly and lucidly, fitting an amazing amount into 90 pages without ever appearing forced or hurried. Anyone interested in abiogenesis will find *Origins of Life* well worth the read. Even if its argument does not completely convince, it provides a novel perspective on the alternatives.

[*Adapted from a review by Danny Yee posted at <http://dannyreviews.com/h/Origins_Life.html>. Used with permission.*]

When is Life?

A recent article in the journal *Science* reviewed the problems and promises of research into the earliest life on earth and what sorts of scientific evidence may remain of these earliest organisms. Beginning with the presumed trace evidence of biological processes in the Martian meteorite, science writer Richard Kerr places contemporary research into the earliest life into its scientific context. Because of the geophysical conditions on earth 3.5 billion years ago and changes in the geologic column in the mean time, scientists expect little more than the faintest traces of the earliest life forms to be detectable. Therefore, contemporary research tends to be very high-tech and based on extremely small earthly samples. On the other hand, research into early life is getting a good deal more help from astrobiology these days. Still, it is a difficult quest even with the best data, instruments, and techniques.

For details, see Kerr RA. Reversals reveal pitfalls in spotting ancient and ET life. *Science* 2002 May 24; 296: 1384–5.

Origins of Existence: How Life Emerged in the Universe

by Fred Adams
New York: The Free Press, 2002,
266 pages.

Reviewed by Keith M Ashman, University of Missouri, Kansas City

In *Origins of Existence,* Fred Adams addresses some of the deepest questions that have been asked by humankind. For much of history, discourse on such topics as how we got here and why there is something rather than nothing has been conducted by philosophers and theologians. By bringing together current ideas in cosmology, astronomy, and biology, Adams makes a compelling case that these questions properly reside in the domain of science. In doing so, Adams not only provides a welcome antidote to the pseudoscientific musings of the "intelligent design" community, but also gives an excellent overview of some of the most exciting developments currently at the forefront of several branches of science.

Adams's task is not an easy one. The evolutionary story that begins with the Big Bang and ends with the appearance of self-conscious life on at least one planet involves many subtle and complex ideas from quantum physics to molecular biology. The first chapter in particular may be heavy going for a lay audience, both because many physics concepts are introduced in quick-fire fashion and because it is not immediately apparent how these ideas relate to the main theme of the book. However, Adams's excellent and often amusing use of analogy eases the reader through this material.

One of the central themes of the book is that the laws of physics and their offshoots in chemistry and biology must take certain forms in order for life to emerge. The geometry and matter content of the universe must be such that galaxies and stars can condense out of the universal expansion. The production of the elemental building blocks of life require that the strong and weak nuclear forces are of a certain strength. Planets must form around stars and have atmospheric and surface conditions that allow the development of simple organisms.

The observation that the laws of nature appear finely tuned to allow biological life to develop is one of the cornerstones of the "natural theology" of William Paley and others, including their philosophical descendents who champion "intelligent design". Surely, such people argue, the fact that the universe has just the right properties for life indicates that a Creator designed it with life as the ultimate goal. This Panglossian line of reasoning is echoed in Joseph Heller's novel *Good as Gold*, when Sid Gold points out that we are lucky to be on a planet with water; otherwise we would all be extremely thirsty.

An alternative perspective that Adams presents is provided by anthropic arguments, as discussed at length in Barrow and Tipler's *The Anthropic Cosmological Principle* (Oxford: Oxford University Press, 1986). While some anthropic ideas seem to me to be more metaphysical than scientific, the "weak" form of the principle effectively removes the "surprise" that we live in a life-supporting universe. Given that we are alive, it would be impossible for us to observe the universe as being anything other than life-supporting. While this argument occasionally terminates door-step conversations with earnest evangelists, it is also a little glib.

There are other approaches to addressing the question of why the laws of physics and physical constants have forms and values that are "just right" for biological life to emerge. One possibility is that a deeper understanding of physics (the development of a "theory of everything") will reveal that only one set of laws and values is possible. The fact that these laws also allow the emergence of biological life might be regarded as a happy coincidence, but we still have the anthropic argument that a universe with laws that did not support life would not be observable.

A more exciting approach, and one that is gaining ground through theoretical advances in quantum cosmology, is that our universe is not unique. The notion of multiple universes is problematic to some scientists partly because of semantic issues and partly because universes other than our own would not be observable. However, the idea is at least consistent with current variants of the Big Bang model, which has provided a remarkably successful explanation of the observed properties of the universe. If there are multiple universes, this raises the possibility that the laws of physics and the values of physical constants may differ from one universe to another. In this case, the vast majority of universes would be lifeless, but some would be life-supporting. We are therefore left, as Adams emphasizes, with an interesting balance between anthropic arguments and Copernican ones. On the one hand our existence requires that we live in a "special" life-supporting universe, but since there are many such universes, ours is not particularly special after all.

In addition to providing an explanation for the apparent fine-tuning of the universe, these theoretical studies also point to why there is something rather than nothing. Since such investigations are essentially addressing the question of what happened "before" the Big Bang, they are obviously speculative. However, they are based on the extremely successful and empirically tested theory of quantum mechanics. One suggestion is that before the expansion of the universe started, the universe was in a state of "quantum foam" in which everyday ideas of space and time become meaningless. For example, there would be no "before" and "after" in such a foam, nor could one define distances between parts of the foam. If this picture is on the right track, our universe could form spontaneously through a process known as "quantum tunneling". Furthermore, this process may be repeatable,

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providing one motivation for the multiple universes hypothesis.

The formation of a universe with life-supporting properties is obviously just the first step in the emergence of biological life. Adams takes the reader from the beginning to the formation of galaxies and stars, the production of the "elements of life" such as carbon and oxygen within stars, the formation of planets in general and the earth in particular, and the emergence and evolution of biological life on the earth. The discussion of how biological life arises from lifeless molecules includes a detailed and clear description of the evidence used by scientists to investigate this fundamental issue.

Despite the complexity of the material, Adams does an excellent job of presenting it at a comprehensible level without losing scientific accuracy. Each chapter of the book begins with a thematic haiku and a few paragraphs of short prose. The latter is stylistically reminiscent of Alan Lightman's *Einstein's Dreams* and provides a somewhat whimsical overview of the material to come. Combined with some delightful illustration and Adams's dry wit, these elements make the book a pleasure to read.

Science is sometimes accused of removing the wonder from life in its reductionist attempts to explain how the universe and the systems within it work. The ideas brought together by Adams provide a powerful counterargument to this accusation. The understanding of our universe that we are gaining through scientific investigation only enhances the wonder. And while we may be a long way from answering all the questions posed in Adams's book, the fact that we continually search for answers is, in my opinion, one of the more attractive qualities of our species.

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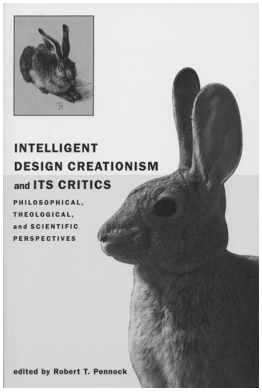

Intelligent Design Creationism and Its Critics: Philosophical, Theological, and Scientific Perspectives

edited by Robert T Pennock
Cambridge MA: The MIT Press, 2001.
xx + 805 pages

Reviewed by Glenn Branch, NCSE Deputy Director

The reaction of the Duke of Gloucester to the second volume of Gibbon's *The Decline and Fall of the Roman Empire* springs irresistibly to mind: "Another damned, thick, square, book!" Pennock's hefty anthology contains no fewer than 37 essays that together comprehensively address the phenomenon of the "intelligent design" movement from (as the subtitle promises) philosophical, theological, and scientific perspectives. The book is divided into 9 sections — intelligent design creationism's "wedge strategy"; Johnson's critique of evolutionary naturalism; a theological conflict? evolution vs the Bible; intelligent design's scientific claims; Plantinga's critique of naturalism and evolution; intelligent design creationism vs theistic evolutionism; intelligent design and information; intelligent design theorists turn the tables; and creationism and education.

"Intelligent design", defined as uncontentiously as possible, is the view that there is scientific evidence for the handiwork of a personal designer — possibly but not necessarily supernatural — in the biological world. As such, it is arguably the descendant of the Bridgewater Treatises (1833–1840), Paley's *Natural Theology* (1802), Ray's *Wisdom of God Manifested in the Works of the Creation* (1691), and so on back to Diogenes of Apollonia, but its contemporary ur-texts are Thaxton, Bradley, and Olsen's *The Mystery of Life's Origin* (1984), Davis and Kenyon's *Of Pandas and People* (1989; second edition 1993), and Johnson's *Darwin on Trial* (1991). Thus the intellectual ancestry of "intelligent design" is principally in creationism, whence the noun in *Intelligent Design Creationism and Its Critics*. Although Pennock traces the ancestry of "intelligent design" in his previous book *Tower of Babel* (1999), there is no essay in the present anthology that covers the same ground — which is regrettable, especially in light of William Dembski's public complaint that its very title is tendentious. Still, any qualm about the title is likely to be assuaged by the realization that "intelligent design's" eschewal of scientific research in favor of political activism and educational propaganda is parallel to creationism's, as Barbara Forrest details in her exhaustive description of the wedge strategy for promoting intelligent design, devised by Phillip Johnson and implemented by the Discovery Institute's Center for (the Renewal of) Science and Culture.

With the exception of the philosopher Alvin Plantinga, the proponents of "intelligent design" represented in Pennock's anthology are associated with the Center for Science and Culture: in addition to Johnson, the Center's advisor, there are Michael Behe, Paul Nelson, and William Dembski — all Senior Fellows of the Center. Also prominent in the activities of the Center is Jonathan Wells, but since Wells's contribution to "intelligent design" consists in *Icons of Evolution* (2000), a screed reminiscent of the worst excesses of the Institute for Creation Research (see reviews by Coyne [2001], Scott [2001], and Padian and Gishlick [2002]), his absence from the book is no loss. Despite the scientific pretensions of the Center, the proponents of "intelligent design" have not managed to produce any relevant scientific articles in the peer-reviewed scientific literature; as Forrest trenchantly

remarks, "the wedge strategy is failing miserably in its most important goal: the production of scientific research data to support 'intelligent design' creationism and the publication of such data in scientific journals."

If there is a scientific component to "intelligent design", it is due mainly to Behe, the only working scientist among the proponents of "intelligent design" represented here, and, significantly, the least extreme in his distance from the evolutionary mainstream. Behe's contribution to "intelligent design" is the concept of irreducible complexity, introduced in his popular work *Darwin's Black Box* (1996) and reiterated thereafter, with negligible changes, in a series of articles in popular publications; Behe argues that certain complex structures at the cellular level could not have arisen through random mutation and natural selection. His microminiaturization of Paley was roundly criticized in the scientific literature on its initial appearance, and the discussions by Philip Kitcher and by Matthew J Brauer and Daniel R Brumbaugh, although worthy, add little to the conversation. It is surprising that Pennock includes no contribution by Kenneth R Miller, the Brown University biologist who regularly debates Behe and whose *Finding Darwin's God* (1999) devotes a chapter to refuting him.

Still, as Johnson confided elsewhere, "This isn't really, and never has been, a debate about science. It's about religion and philosophy" (Belz 1996). For Johnson, the project is clear: to argue that evolution "is based not upon any incontrovertible empirical evidence, but upon a highly controversial philosophical presupposition" — which, of course, he rejects on theological grounds. Unfortunately for his project, Johnson appears to be as poorly equipped for philosophical disputation as he is for scientific inquiry. Reading through his exchanges with Pennock on methodological naturalism and with Richard Dawkins and George C Williams on genetic information, it is difficult to decide in which area he exhibits less acumen. Less lively but still interesting are the theological critiques of Johnson offered by Nancey Murphy and Howard J Van Till, whose poignant assessment of "intelligent design's" presumption that evolution threatens Christianity deserves quotation: "a tragedy of major proportions for the Christian witness to a scientifically literate world." In the same section of the book, although not addressing Johnson specifically, is Arthur Peacocke's Idreos Lecture "Welcoming the 'disguised friend' — Darwinism and divinity" — itself a welcome contribution.

Unlike Johnson, Plantinga is undeniably possessed of philosophical acuity, which he deploys here against methodological naturalism — crudely, the view that science is able to investigate only the natural world — at a level of philosophical sophistication apparently beyond Johnson's reach. In "Methodological naturalism?" he argues, on the basis of his celebrated view about the proper basicality of Christian belief, that Christian believers are not obligated to practice science as methodological naturalists. In his response, Michael Ruse justly castigates Plantinga for "a deliberate ignorance of work that is going on today in science" that encourages him to underestimate the value of methodological naturalism. Ruse also remarks that Plantinga's rejection of methodological naturalism is premised on "his prior commitment to his own version of Christian theism"; in their exchanges with Plantinga reprinted from the *Christian Scholar's Review*, Van Till and Ernan McMullin demonstrate that not all Christians share Plantinga's repugnance for methodological naturalism.

Plantinga's rejection of methodological naturalism is bolstered by his argument (reminiscent of CS Lewis's) that philosophical naturalism — crudely, the view that the natural is all that there is — is self-defeating. Pennock fails to explain that the argument is not aimed against evolution per se: as Plantinga himself notes, a theist who accepts the argument "may indeed endorse some form of evolution; but if he does, it will be a form of evolution guided and orchestrated by God" (Plantinga 1993: 236). But, as his "When faith and reason clash" suggests, Plantinga thinks that the untenability of naturalism clears the way for the creationist: "The believer in God, unlike her naturalistic counterpart, is free to look at the evidence for the Grand Evolutionary Scheme, and follow it where it leads, rejecting that scheme if the evidence is insufficient" — as he evidently supposes that it is. So it is, after all, appropriate that Pennock includes a pair of excellent, if technical, articles (by Evan Fales and by Brandon Fitelson and Elliott Sober) criticizing Plantinga's argument; those interested in the debate should consult Beilby (2002) and chapter 7 of Plantinga (2000) for the latest developments.

Finally, in the last section of the anthology, Plantinga and Pennock philosophically spar about whether it is appropriate to teach creationism in the public schools. It is not at all surprising that the science writer for the Columbus, Ohio, *Dispatch* publicly recommended the exchange (as well as Forrest's contribution) to members of the Ohio Board of Education, who were recently beset by creationists eager for "intelligent design" to be included in the state science standards. Pennock, whose response includes a brilliant refutation of a specious appeal by Plantinga to John Rawls's theory of justice, is the clear winner here; the fact that the Ohio state science education standards explicitly disavowed any intention of mandating teaching of or testing on "intelligent design" suggests that the Ohio Board of Education prefers Pennock's vision of science education to Plantinga's.

Compared to Plantinga's, Nelson's and Dembski's contributions are philosophically negligible. (It is unfortunate that Pennock includes nothing by Del Ratzsch, a philosopher of science influenced by Plantinga; his work [2001], which is sympathetic to, if not quite so invested in, "intelligent design", is of substantially higher philosophical quality.) Nelson is a young-earth creationist — he comes by it honestly; his grandfather Byron C Nelson was a prominent anti-evolutionary pamphleteer of the 1930s — but there is no trace of it in his essay here, in which he soberly argues that evo-

lutionary biologists are prone to make theological assumptions that are not only unjustifiable but inconsistent with their professions of methodological naturalism. To Kelly C Smith's withering response, it is necessary only to add that the texts that Nelson examines are popular works and introductory textbooks, not the sort of writing that evolutionary biologists professionally produce.

And then there is Dembski, who is rapidly consolidating a reputation as the *enfant terrible* of "intelligent design" — not so much on account of his youth as of his combativeness, his ceaseless self-promotion, and his tendency to put his foot in his mouth (as when he told *The Chronicle of Higher Education* [McMurtrie 2001] that he prefers publishing popular books to scholarly articles because "I get a royalty. And the material gets read more"). In "Intelligent design as a theory of information" (1997; reprinted with revisions as chapter 7 of *Intelligent Design: The Bridge Between Science and Theology* [1999]; reprinted in part with revisions as chapter 3 of *No Free Lunch* [2002]), Dembski argues that "information is not reducible to natural causes", a claim that Peter Godfrey-Smith exposes as a restatement of the antediluvian creationist canard about the improbability of evolution. Dembski's so-called explanatory filter is the main topic of Branden Fitelson, Christopher Stephens, and Elliott Sober's review of *The Design Inference* (1998); it is unfortunate that Pennock includes no explanation by Dembski himself of the filter. Finally, in "Who's got the magic?", Dembski argues that evolutionary biology relies in effect on appeals to magic ("getting something for nothing"); it is noteworthy that, when it was reprinted as the final section of *No Free Lunch*, Dembski failed to respond to "The wizards of ID", also reprinted here, in which Pennock convincingly replies that it is, on the contrary, "intelligent design" that relies on magic.

Pennock, whose *Tower of Babel* remains the most important philosophical evaluation of the "intelligent design" movement available, provides a brief preface to each of the sections as well as to the book itself; while not disguising his intellectual antipathy to the "intelligent design" movement, Pennock admirably manages to provide a balanced (if not equal) selection of essays that is essential reading for anyone interested in investigating the relationship between science and theology. For, as *Intelligent Design Creationism and Its Critics* shows, the "intelligent design" movement conceives of the relationship in a particularly counterproductive — and even disastrous — way.

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Responses to 101 Questions on God and Evolution

by John F Haught
Mahwah (NJ): Paulist Press, 2001.
160 pages

Reviewed by Phina Borgeson, NCSE Faith Network Project Director

It may be flippant, or just bad theology, to speak of this small volume as an answer to prayer. But for those who want the fruits of reasoned thinking on evolution and Christian theology in a format that may be mined for succinct answers, this is the book of choice. Dip in anywhere, to any of the 101 questions, and you will get a clear, and often quotable, response.

Haught's *Responses to 101 Questions on God and Evolution* joins some excellent companions in the Responses to 101 Questions series from Paulist Press, which seems to be designed to help Roman Catholic laity deal with contemporary topics, and perhaps especially to help middle-aged church members get the straight scoop on topics on which popular Catholic thinking has changed in recent years. Several books in the series, among them *101 Questions on the Bible* (Mahwah [NJ]: Paulist Press, 1990) by the late Raymond E Brown SS, epitomize clear writing by academics for a popular audience. Haught's joins their number.

The book begins with a series of questions about "Darwin's revolutionary idea". Darwin's life, work, and continuing relevance are outlined. In subsequent chapters, Haught tackles Darwin and theology, creationism, Catholic teaching and evolution (including original sin), and the necessity of developing a theology of evolution. Throughout he weaves, or at least braids, several strands of 20th-cen-

tury theological traditions. At the same time he gives a nod to ethical issues, such as environmental crises and genetic manipulation, to which an evolution-informed theology is relevant.

Readers of *RNCSE* will of course be curious to know what Haught says about creationism and "intelligent design". Haught directly addresses questions popular with evolution's detractors, such as "Has anybody actually observed evolution taking place?" and "Isn't evolution merely a theory?" A typical answer to the latter question is "Theory is not something which dissolves or disappears once we get to the 'facts.' It abides as the intelligible context in which all facts are identified as such" (p 13). In question 63, he asks himself, "Aren't you being too hard on the proponents of 'intelligent design' theory?" No, he replies, because "intelligent design" is, in effect, a demotivator for doing science. "If we have to appeal to the notion of God every time we meet an impasse in scientific inquiry, what is the point of doing science at all?" (p 89).

Readers of Haught's more discursive volume, *God After Darwin* (Boulder [CO]: Westview, 2000), will recall that he constructs an excellent argument against "intelligent design" from a theological perspective. Chapter 4 here, "Darwin and design", reiterates that reasoning; Haught's major theological complaint with "intelligent design" is that it closes off the future:

> If God is pictured only as a designer, the world that this God "designs" would have no future. It would be a dead and finalized order, closed off to any new becoming. A world sealed shut to novelty would be utterly lifeless. A one-sided obsession with "intelligent design", therefore, suppresses the biblical trust in a God whose creative "word" is always a word of promise. A promising God is *still creating* the world, apparently through evolutionary means. Through evolution creation is opened up widely to indeterminate future outcomes. "Intelligent design" seekers are not looking to the future, but to a dead past. Darwin, on the other hand, impresses upon us the fact of an unfinished cosmos. This, in turn, allows us to recapture the theme of promise, the central theme in the Bible's vision of God (p 92, emphasis in original).

On the educational front, Haught is compelling in his exposition of reasons to keep ideological claims — whether biblicist or materialist — out of the science classroom. "Teaching biblical creation accounts in the classroom implicitly desacralizes revered writings whose intention is to open up to holy mystery, not to enhance our store of scientific knowledge. Since science was not even remotely part of the biblical author's culture, they could not possibly have been trying to teach their readers scientific truths" (p 73–4). And he adds, "Ironically, it is only because creationists already tacitly accept modern science as the authoritative road to truth that they are so eager to have biblical creation narratives taught in science classes. The biblical authors themselves would be extremely puzzled at current efforts to force their ideas into such a restrictive framework" (p 74).

The format of the *Responses to 101 Questions* series, though, unfortunately limits the book's usefulness. Perhaps footnotes are scary to the average reader, but citing books and people referred to and expanding the resource section would have made this volume an invitation to thinking about evolution theologically, not just a stand-alone resource. And while the table of contents is exhaustive, listing every question Haught deals with, the questions are not always the best clue to the content of the answers. An index would have really helped the reader to recover key information. The editors of the series should consider whether making a book look less formidable really makes it more useful.

As for the content of Haught's book, there are two areas in which I think it misses opportunities to connect with popular piety. First, Haught neglects to engage fully with the biblical texts on creation beyond Genesis 1–3, although he does mention them. Yet he offers no real exposition of the ideas contained in the Psalms, the rest of the writings, the Gospel of John, and the letters of Paul. Given the upsurge in interest in Bible study by members of the Roman Catholic Church since Vatican II, expanding his reader's notion of God's creativity as reflected in Hebrew and Christian scripture would build on interest that is already there, and stretch the scripture–evolution dialogue beyond rehashing those opening chapters of the Pentateuch.

Second, Haught neglects to address the renewed interest in the Holy Spirit. In the Roman Catholic Church as well as in many other Christian communions, there is a revival of attention to the third person of the Trinity, which can contribute to the constructive connection of creation and evolution (as in the writings of Denis Edwards and Jürgen Moltmann). Yet there is little or no explicit discussion of the Spirit in *Responses to 101 Questions on God and Evolution*.

Even with these shortcomings, Haught's latest volume deserves to find a place on the shelves and in the hands both of those heavily involved in the science–religion dialogue and of those pastoral and educational ministers responding to questions of believers and inquirers. Haught's work is constructive and important. In his own words: "… too much time and energy is wasted trying to show that evolution is wrong, when religious believers should be asking whether our understanding of God might not be too small to accommodate Darwin's world" (p 100).

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