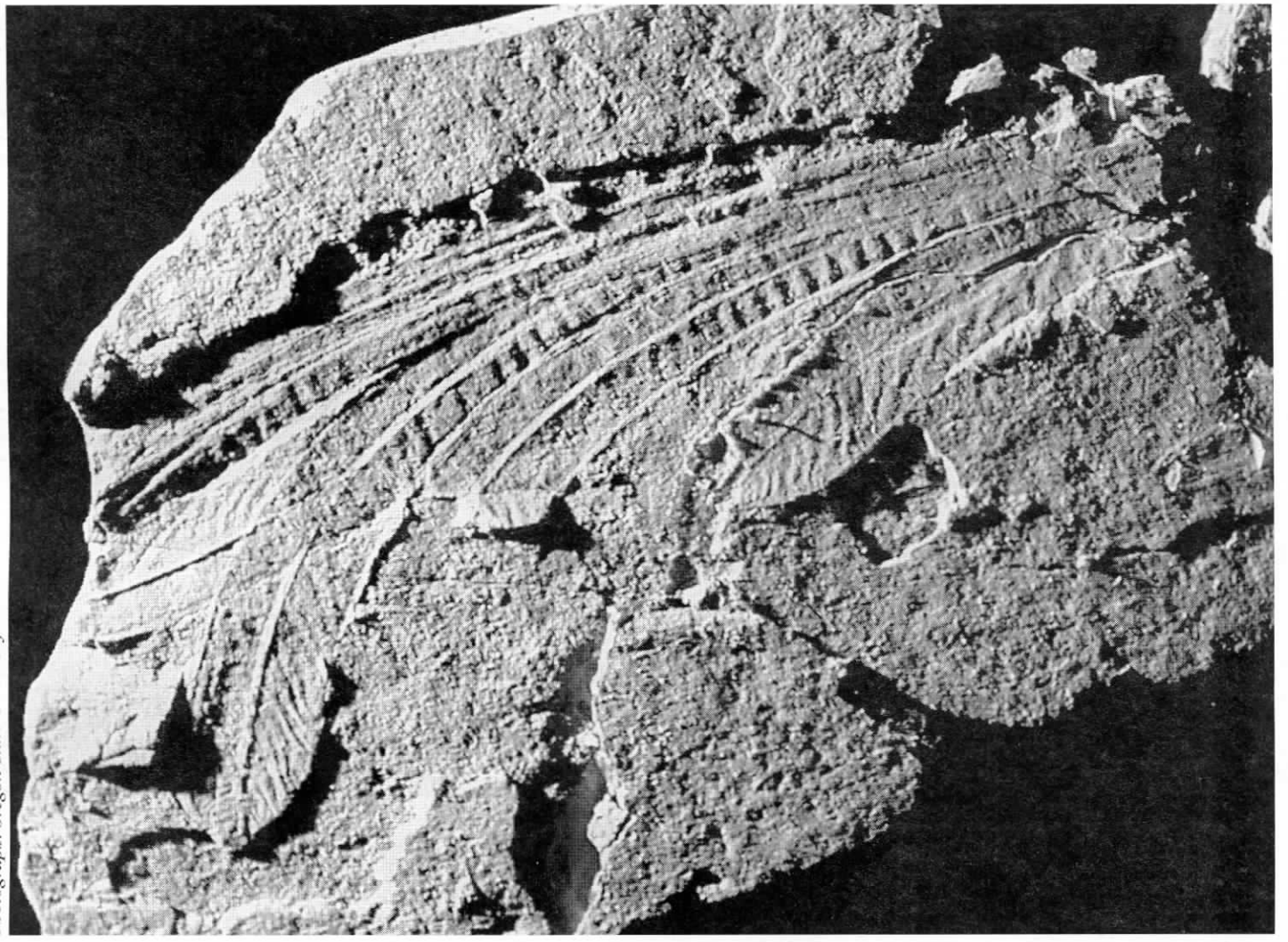
REPORTS OF THE NATIONAL CENTER FOR SCIENCE EDUCATION

DEFENDING THE TEACHING OF EVOLUTION IN THE PUBLIC SCHOOLS

Volume 20, Number 5 SEP/OCT 2000

CONTINUES *NCSE REPORTS* & *CREATION/EVOLUTION*



Photograph: Oregon State University

Anti-Evolution Legislation Resurfaces in Several States

Hoofed Ancestors for Whales? The Fossils say Yes!

Sermon under the Mount — Spelunking with Kurt Wise

Original Spin: Creationist Tales of Animal Origins

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VOLUME 20, NR 5, SEP/OCT 2000
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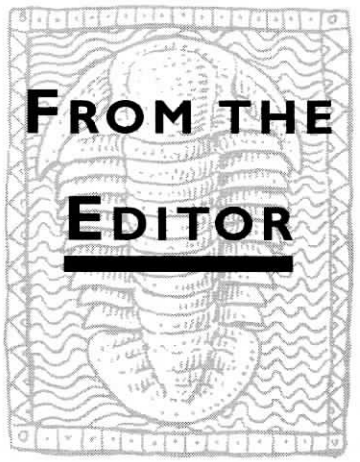
Cover: Impressions from the back of *Longisquama* (see p 28).

FROM THE EDITOR



What is a fossil? When students answer this question, they often think of petrified animal skeletons and, only occasionally, of petrified plant remains. Even after they realize that "fossil" refers to any preserved remains or trace of organisms living in the past, students view the constructed and "embodied" remains as actual ancestors to modern living organisms. Each organism is a mixture of biological features shaped by its heritage and its environment, and it passes on some of those features to its descendants. It is this mixture of features — some retained from ancestors, some modified and put to new use, and some passed on to descendants — that define for scientists an intermediate form or transitional fossil. And intermediate forms are what tell us something about the pathway that evolutionary change has taken in various groups of organisms. However, contrary to anti-evolutionists' straw-man arguments, paleontologists never expect to see a fossil of one organism "turning into" another. Each of these fossil organisms must be understood in terms of its own anatomical features and ecological role — not just in terms of its potential for becoming something else.

Evolution? The fossils speak volumes

In this issue we examine the offerings of the fossil record. What do those preserved remains represent? What should we expect from them? How should we use them to understand the history of life on earth?

Nigel Hughes examines the so-called Cambrian explosion and how the fossil record of ancient animal life is distorted by anti-evolutionists. Although several major innovations in the diversity of animal life were present in the Cambrian, there was still a whole "lotta 'volvin' goin' on". Contrary to the current anti-evolutionist spin on the Cambrian explosion, Hughes points out that Cambrian animals were still very distant relations to the subphyla, classes, and families that exist today. He also demonstrates that the claim in Jonathan Wells's *Icons of Evolution* that "major animal phyla and classes appeared right at the start" of the Cambrian is an inaccurate interpretation of the fossil evidence.

NCSE's President Kevin Padian brings us up to date on the latest in the evolution of birds from dinosaur ancestors. Although anti-evolutionists take comfort from the few scientists who claim that birds did not have dinosaur ancestors, Padian makes it clear that all parties to the scientific debate agree that birds emerged from reptilian ancestors. He demonstrates how scientists determine the most likely ancestry of birds by the use of an analytical tool called a cladogram.

Finally, Ray Sutera's update on whale evolution explores the explosion in the data for this taxon of mammals. A series of fossils shows both anatomical links between whales and their proposed terrestrial ancestors and an ecological distribution that chronicles an increasing independence from the land. Furthermore, Sutera describes the findings from a variety of scientific fields — from biochemistry through embryology — that confirm the evolutionary pattern presented by the fossil record.

Notes from all over

There is much afoot in the nation and elsewhere. As we go to press, the struggle to preserve evolution in science education standards and in precollege teaching goes on. In Arkansas, the latest incarnation of anti-evolution legislation was defeated quickly. There are also anti-evolutionary legislative proposals in Michigan and Louisiana. In Minnesota, Rodney LeVake's attempt to teach "the evidence against evolution" suffered another setback.

Our members have been a very busy lot. Read about their activities in support of evolution throughout the country, and be sure to check out the special feature on our members in Washington's Burlington-Edison District. If you have been active in your community or state, drop us a line to tell us all about it.

Looking Ahead

There have been so many new books about evolution (and creationism) that we have been having trouble finding enough space in our issues to review them all. So the next issue of *RNCSE* will be a special "book review" issue. We will begin volume 21 with a special essay by John Wilkins on the definition — one might say definitions — of evolution and how the theory and the concept have changed over the past century and a half.

Anj Petto

RNCSE 20 (5) was printed in July 2001.

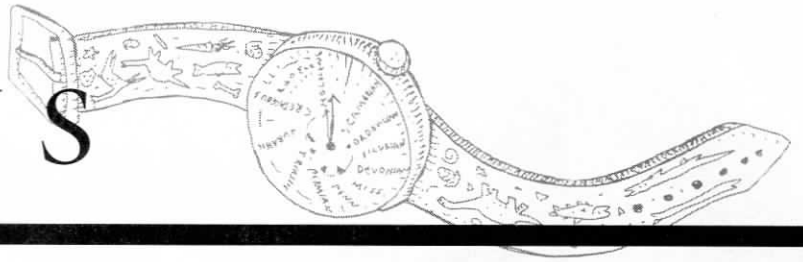
Errata

Attentive readers noticed two typographical errors in the articles on radioactive dating in *RNCSE* 2000; 20 (3).

In Derek York and G Brent Dalrymple's "Comments on a Creationist's Irrelevant Discussion of Isochrons", on p 25, the rightmost subscript in the displayed equation is *s*; it should be *c*. (The version of the same equation in the Appendix on p 27 is correct.)

In Dave Thomas's "Nuclear Isochrons", on p 27, at the bottom of the second column, the daughter isotope is parenthetically referred to as ^{87}Rb; it should be ^{87}Sr.

NEWS



Slow but Steady Progress for Evolution Education in Ohio

Steve Edinger

On May 2, 2000, Ohio State Representative Ron Hood (Republican, 57th district) introduced House Bill 679 (HB 679), one of the new forms of "equal time" bills. The bill would require that whenever evolution is taught in Ohio's public schools, "... both scientific evidence supporting or consistent with the theory and scientific evidence not supporting or inconsistent with the theory shall be included." Hood introduced the same bill in 1996, as HB 691. Both bills had a significant number of vocal supporters. In both cases, a strong, active opposition helped to defeat the bill.

During public hearings for HB 691, it became clear the supporters of the bill saw it as a green light to teach creationism under the guise of "evidence against evolution". According to supporters, among the ideas that teachers would be free to teach or discuss in the classroom under HB 691's provisions are:

- The insufficiency of mutation and natural selection to produce new traits.
- The unreliability of radiometric dating methods.
- The lack of any transitional forms in the fossil record.
- Scientific proof that the earth is no more than 12 000 years old.
- The complicated design of living things as proof that there must be an intelligent designer.

Finally, there were a couple of teachers and students who said that HB 691 would allow them to "... share their faith in the classroom, telling other students about the biblical account of creation." This last group of witnesses probably did more to scare representatives away from HB 691 than the combined testimony, letters, and e-mails from scientists, parents, and educators opposing the bill!

Both HB 691 and HB 679 died quietly in committee. Although Hood was able to get eight other Republican representatives to cosponsor HB 679 (including the Vice Chair of the House Education Committee and two other members of the House Education Committee), no action was taken on the bill. HB 679 never even had a hearing for public comments. Perhaps more significantly, Hood, who vowed in 1996 to keep reintroducing this bill until it became Ohio law, lost his seat to Democrat John Boccieri in a close race (51.9% to 48.1%). Without a crystal ball, it is impossible to say whether one of the cosponsors of HB 679 or some other representative will reintroduce it in the next legislative session, but it seems unlikely.

Independently, Ohio's State Board of Education has adopted competencies for the revised 12th-grade proficiency tests that require some knowledge of evolution. It is interesting that the "e-word" is used in conjunction with cosmic evolution and earth history, but not with biology. There was opposition on the school board to including evolution and to including evolution without including creationism. A motion proposed by board member Deborah Owens Fink to adopt a "two-model" system with time for evolution and creationism failed by a 9-5 vote. The motion adopting the competencies passed by a 12-2 vote. The active, vocal support of scientists, science educators, parents, and the Ohio Academy of Sciences helped to persuade the Board to keep evolution in Ohio's competencies and creationism out.

Ohio currently requires high school students to pass a 9th-grade proficiency exam to graduate from high school and is moving toward requiring a 12th-grade proficiency exam. Both exams are based on the state's competencies. The 12th-grade competencies including evolution or information important to evolution require students to:

10. Interpret astronomical observations within and beyond the solar system and relate these to our understanding of earth.

12. Demonstrate an understanding of energy in the earth system, geochemical cycles, origin and evolution of the earth system, and origin and evolution of the universe.

15. Relate patterns of diversity, extinction, adaptation, and speciation as a result of natural selection at the molecular and population levels.

The K-12 competencies of Ohio's State Board of Education are part of a larger educational overhaul in Ohio. The Joint Council of the Ohio Department of Education and the Ohio Board of Regents is working on devising K-16 competencies. These competencies are intended to ensure the education students receive at one level is appropriate and prepares them to step up to the next level. Ideally all graduates from Ohio's public colleges and universities will acquire at least a certain level of skills while in college. Draft standards for mathematics and English are written and under

review. Work on the science standards began in January 2001. Supporters of evolution education are ready to make their voices heard again!

The Joint Council consists of members of both the Ohio Board of Regents and the State Board of Education. I would expect (and I hope) that all the members of the Board of Regents take a very dim view of including creationism, excluding evolution, or including an "equal time" provision in the science standards. However, one member of the Joint Council, Dr Deborah Owens Fink from the State Board of Education, strongly supported including creationism or qualifiers about evolution in the competencies drafted by the State Board of Education.

Educating Ohio students about evolution seems to be moving ahead gradually rather than punctually!

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Bad Religion, Good Science

The veteran punk band Bad Religion, whose latest album is *The New America*, maintains a research fund to support scientific fieldwork by US high school and undergraduate students. Surprised? Don't be: the lead singer, Greg Graffin, is working on his PhD in Zoology at Cornell University, and the other members of the band are also keenly interested in science. Recent projects supported by the Bad Religion Research Fund studied the physiological effects of excess atmospheric carbon dioxide on plant ecosystems, the invertebrate cave fauna of the Great Smoky Mountains, and the dispersal of mycorrhizal fungal spores by rodents. For more information, visit the band's web site — which "is always evolving, sometimes slowly, sometimes in punctuated bursts" — at <http://www.badreligion.com>.

Anti-evolution Bill Down and Out in Arkansas — For Now

Eric Meikle
NCSE Outreach Coordinator

Creationism resurfaced in a variety of state legislatures this spring. On March 5, 2001, Rep Jim Holt, a first-term legislator, a chaplain by profession and a counselor at a youth treatment center, introduced HB 2548 in the Arkansas legislature (*see the amended text of the bill at <http://www.arkleg.state.ar.us/ftproot/bills/2001/htm/HB2548.pdf> or on p 7*). Some of the bill's text came from Jack Chick's cartoon tract "Big Daddy" (*see <http://inia.cls.org/~ae/ar_hb2548.htm> for an analysis of the bill and its language*).

On March 21, the bill was heard in the State Agencies and Governmental Affairs Committee. Opposition came from Rita Sklar (the executive director of the Arkansas Civil Liberties Union) and Dr Robyn Hannigan (a geologist in the Department of Chemistry and Physics of Arkansas State University) among others. One representative asked Sklar whether she believed in evolution. She said that she did. He then asked, "So, you think you were descended from a monkey? Do you think if you teach children they were descended from animals they will act like animals?"

Evangelist Kent Hovind spoke before the committee on behalf of the bill, claiming, "We're not against science. We're just against lies." His testimony included statements that "Haeckel's embryos" helped to spread belief in evolution in Germany, which led to belief in the superiority of the Aryan race, and thus to Nazism and World War II; and that the human "gill theory" is still being taught in Arkansas as fact. Hovind went on to say that Holt's bill is not aimed at removing evolution from classrooms, despite his claim that it is wrong to teach children that scientists have evidence of evolution; that much of the so-called evidence has been disproven; and that he will pay $250 000 to anyone who can prove the theory of evolution (*Hovind's version of the events in Arkansas may be found at <http://www.drdino.com/Articles/Arkansas.jsp>*).

Holt rhetorically asked whether taxpayer dollars "should go to [promulgate] fraudulent information". In the end, the committee approved the bill with only one "no" vote and sent it back to the House. On March 22, another legislator objected to the lack of a required financial impact statement. Holt said the statement was on its way and asked that the rules be suspended to consider the bill without it. This attempt was defeated, 47–44, suggesting that at least 44 members were ready to vote for Holt's bill right then.

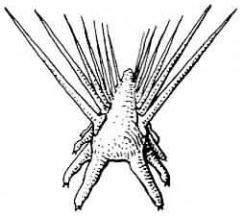
On March 23, the bill again was scheduled for consideration in the House. This time there was a rather lively floor debate. One legislator, after confirming that Kent Hovind had been the "expert" in the committee hearing, brought up Hovind's history of legal problems. Other opponents used an economic argument. One had spoken to a legislator in Kansas who said that recruitment and business had been hurt there after the State Board of Education stripped evolution from its science education standards in 1999.

At least some legislators seem to have remembered Arkansas's history of anti-evolution laws and legal activity. Said one, "This law is clearly unconstitutional. Folks, if we pass this, we will not be shooting ourselves in the foot; we'll be shooting our foot off." Editorial writers in the Arkansas press were similarly unenthusiastic about Holt's bill (*see, for example, <http://www.thecabin.net/stories/032701/opi_032701002 6.shtml>, <http://www.arktimes.com/bob/033001bob.html>, and Don Michael's article, following*).

In the end, 45 members voted "yes", 36 "no", with 19 either "present" or not voting. The measure failed to achieve the 51 votes necessary to pass. Afterward, Holt repeated that he is only trying to set the scientific record straight and that the bill only cites evolution examples because they are the most apparently false. Although some observers thought this meant the end for this bill, parliamentary maneuvers allowed it to remain technically alive.

On April 3, a motion to expunge, or set aside, the previous vote failed, despite getting 62 "yes" votes and only 22 "no", because this action requires 67 votes. However, on April 12, another motion to expunge the March 23 vote passed with 71 "yes" votes. A further motion to postpone consideration of the bill indefinitely, and to refer it to the Joint Interim Committee on Education, passed with 70 "yes", 5 "no", 4 "present", and 21 not voting. Thus there is a possibility that an amended version of this bill will reappear at some point in the next two years.

[NCSE thanks Rita Sklar, James Murray, and members of the Arkansas AIBS evolution listserve for information used in this article.]



Holt, Wells, and Textbooks: The Arkansas Anti-evolution Bill

Don Michael

Whenever the Religious Right comes up with a new conspiracy surrounded by bizarre and peculiar facts, you can bet someone in their ranks, somewhere, has written a book.

That is what happened when Pat Robertson's *The New World Order* spawned erratic theories in 1992 concerning attempts by the United Nations and world leaders to form a one-world government.

This tendency is apparently rearing its head again in state Rep Jim Holt's new bill on evolution.

House Bill 2548 sounds good from its title: It proclaims itself an act to "prohibit state agencies and other public entities from using tax dollars to purchase or distribute material (containing) information which has been proven false or fraudulent."

Read further, and Holt will take you on a ferry ride down the right's latest arsenal of anti-evolution trickery.

Tactics against this widely held scientific theory, much like the creationism that fathered the conflict, have changed over the years.

When the Scopes Monkey Trial was beginning in 1920s Tennessee, the most common route was simply outlawing evolution. Many felt it conflicted with Genesis, and therefore would prompt children to reject God, baseball, and apple pie. In 1968, the US Supreme Court overturned Arkansas's law banning evolution to provide the national precedent we enjoy today.

When efforts to ban evolution failed, an array of creationist theories evolved, and the purpose shifted from eradicating evolution to finding pieces of evidence supporting creationism and cramming them into religious theory. By doing this, fundamentalists felt they could declare creationism a science, too.

But the courts did not buy that either.

A full-blown trial dubbed "Scopes II" commenced in Arkansas in 1982 over a law requiring creationism to be taught alongside evolution. The judge ruled it unconstitutional but the state did not appeal. Eventually, a similar law in Louisiana was rejected by the Supreme Court after justices held that teaching creationism — a religious, not scientific, theory — violated the US Constitution by establishing religion.

To avoid constitutional entanglement, anti-evolutionists have turned to simply attacking evolution in an effort to keep it out of schools.

And thus, Holt's bill wriggled up out of the murk.

In reading the bill, you come away thinking Holt has considerable scientific knowledge for a chaplain/counselor and state representative. A laundry list of things reportedly "false" in evolution textbooks can leave the impression he has done a lot of research on the topic.

But Holt's bill is not as mysterious when you read excerpts of the latest book fundamentalists are buying by the truckload: Jonathan Wells's *Icons of Evolution*.

Who is Jonathan Wells?

Religious leaders found out

Don Michael is the opinion page editor of the Northwest Arkansas Times.

Creationism Philosophically Defined

The Oxford Dictionary of Philosophy (New York: Oxford University Press, 1994) contains the following succinct definition and critique of creationism on page 88:

> In the philosophy of biology, the belief that perceived difficulties or gaps in the scientific theory of evolution by natural selection are well filled by positing Divine intervention, to create new species, and certainly to create people. Even when it does not depend upon misunderstanding the theory of evolution, the doctrine is unscientific because it simply postulates a God-sized cause for whatever gap is currently of interest: this leads to no falsifiable predictions or unification of knowledge.

The author, Simon Blackburn, is Professor of Philosophy at the University of Cambridge.

long ago that the educated public had stopped believing pastors over noted scientists in matters of scholarly affairs. So Wells, a Unification minister, set out to get a PhD in biology in 1989 to "devote my life to destroying Darwinism."

Wells's approach to the topic is parallel to the problems facing creationists. Instead of objectively observing and collecting evidence and applying natural law and hypotheses to conclude a theory, like scientists do, they take a narrow premise and then set out to find evidence to support it. Likewise, Wells got his education with the sole intent of discrediting evolution.

In his book, Wells alleges the scientific community is orchestrating a worldwide conspiracy to cover-up evidence that casts doubt on evolution so it can continue some sort of aversive agenda. If that sounds crazy, that is because it is.

For instance, Wells claims noted scientific historian Stephen J Gould has known Ernst Haeckel's embryos were fake depictions but has kept his mouth shut about it. Gould has not kept his mouth shut — or his pen. He in fact published a book about the subject more than 20 years ago.

The embryos get a lot of attention in Holt's bill, and the representative outlined much of Wells's other supposed evidence of fraud, including Wells's allegation that a picture portraying peppered moths is fake because the moths are actually dead and glued to a tree. It is true the picture is of dead moths, but ask any knowledgeable scientist and they will tell you they were pasted there to test the reactions of predatory birds, not as some form of fakery.

Not to mention the fact that several scientists quoted in Wells's book have written rebuttals, saying they were misquoted or their comments were taken out of context.

All of this in the latest chapter of evolution vs creationism, two things not always viewed as mutually exclusive.

Why do anti-evolutionists feel so endangered by this specific theory but not others developed by the same scientists they assail? Many people comfortably integrate evolution into their religious beliefs, and some denominations have even adapted evolution into their stated doctrines.

In the meantime, those threatened by Darwin and evolution are continuing their crusade to alter, deceive, or distort scientific teachings for the rest of us. But considering how their tactics and beliefs have changed over time, maybe there is hope for the future.

Perhaps eventually, their logic will rise to the upright position.

Reprinted by permission from the Northwest Arkansas Times, *March 23, 2001.*

AUTHOR'S ADDRESS
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Arkansas House Bill 2548

By: Representatives Holt, *Fite, Prater, Mack, Nichols, Adams, M. Smith, Bennett, Duggar, Green, Altes*
By: Senators Critcher, Hunter, Baker

BE IT ENACTED BY THE GENERAL ASSEMBLY OF THE STATE OF ARKANSAS:

SECTION 1.

(a) No state agency, city, county, school district, or political subdivisions shall use any public funds to provide instruction or purchase books, documents or other written material which it knows or should have known contain descriptions, conclusions, or pictures designed to promote the false evidences set forth in subsection (d) of this section.

(b) State agencies, public school districts, museums, zoos, and all political subdivisions of the state shall only provide information that is as accurate as possible.

(c)(1) During classroom instruction conducted by state agencies, museums, zoos, public schools, and political subdivisions of the state, when any statement in instructional material is identified by the instructor to be a false evidence under subsection (d), the instructor shall instruct the class to make a marginal notation that the statement is a false evidence under this act.

(2) During classroom instruction conducted by state agencies, museums, zoos, public schools, and political subdivisions of the state, when any statement in instructional material is identified by the instructor to be a theory, the instructor shall instruct the class to make a marginal notation that the statement is a theory.

(3) Example of such theories include, but shall not be limited to:

(A) The theory of the age of the earth;

(B) The theory of the origin of life;

(C) The theory that homology in vertebrate limbs is evidence for common ancestry;

(D) The theory that the "geologic column" accurately represents different time periods on earth. The "geologic column" does not exist anywhere on the earth, except in textbooks; and

(E) The theory that fossils represents missing links between life forms. It can not be proven that any fossil had any offspring.

(F) Carbon, Radioisotope Dating;

(i) Shells from living snails were carbon dated as being 27 000 years old;

(ii) One part of the Vollosovitch Mammoth carbon dated at 29 500 years and another part at 44 000 years; and

G) Potassium Argon Dating. Basalt from Mount Kilauea Iki, Hawaii in 1959 gave a K-Ar age of 8 500 000 years old.

(d) The General Assembly finds that:

(1) Science is a special way of knowing and understanding the physical world that uses the "scientific method" to conduct rigorous investigations into processes that are observable and repeatable;

(2) Science is a discipline that employs skeptical peer review and experiments attempting

to falsify ongoing and prior scientific work to ensure the validity and integrity of results;

(3) Many ideas and evidences of prior scientific work once believed to be true have been proven false or even fraudulent in many cases, including, but not limited to the following:

(A)(i) Haeckel's Embryos;
(ii) Proven false in 1874 by Professor Wilhelm His, Sr. Ernst Haeckel was convicted of fraud for this in 1874. Human embryos never have gills — not even rudimentary ones;

(B)(i) The Miller - Urey Experiment;
(ii) Scientists have never proven that this test represents the atmosphere at any time on earth.

(C)(i) *Archaeopteryx* as a missing link;
(ii) An X-ray resonance spectrograph of the British Museum fossil showed that the material containing the feather impressions differed significantly from the rest of the fossil slab.

(D)(i) Peppered Moths;
(ii) The photographs used in current textbooks are fraudulent as the moths were discovered to be dead and glued in place.

(E)(i) Fossil Horses;
(ii) It is fraudulent to state that modern horses descended from fossil horses with four toes.

(F)(i) Heidelberg Man;
(ii) Built from a jaw bone that was conceded to be quite human;

(G)(i) Nebraska Man;
(ii) Scientifically built up from one tooth and later learned to be the tooth of an extinct pig;

(H)(i) Piltdown Man;
(ii) The jawbone actually belonged to a modern ape;

(I)(i) Peking Man;
(ii) Supposedly 500 000 years old. Ten humans were found with the "Peking Man" along with crushed monkey skulls and tools.

(J)(i) Neanderthal Man;
(ii) At the International Congress of Zoology (1958) Dr AJE Cave said his examination showed that the famous Neanderthal skeleton found in France over 50 years ago is that of an old man who suffered from arthritis;

(K)(i) *Homo erectus* (originally "Java Man" and later *Pithecanthropus erectus*) was made from a few scraps of bone found in 1891.
(ii) The skull cap came from an ape and three teeth and thigh bone (50 feet away) came from a human. Two normal human skulls were also found, but purposely hidden for 30 years.

(L)(i) Cro-Magnon Man;
(ii) One of the earliest and best-established fossils is at least equal in physique and brain capacity to modern man;

(M)(i) "Lucy;"
(ii) Charles Oxnard studied 16 years and used computer multi-variant analysis and concluded "Lucy" is not intermediate

(N)(i) Vestigial Structures;
(ii) As science improves, our knowledge of the body has increased and functions of parts formerly thought to be useless are becoming known; and no proven vestigial structures exists.

(O)(i) Lobe-fined fish;
(ii) Lobe-fined fish are "index fossils" for rock 325-410 million years old. These fish are still alive today. "Coelacanth" was found in 1938 and still inhabits the Indian Ocean. It is obvious that it cannot be an "index fossil" for any age rock.

Rodney LeVake Loses Appeal

Eugenie C Scott
NCSE Executive Director

Rodney LeVake has again failed in his effort to argue that he had free exercise, free speech, and due process rights to teach "evidence against evolution". On May 8, 2001, the Minnesota Appeals Court supported the summary judgment dismissal decision of the Minnesota District Court of last year (*see* RNCSE *2000; 20 [1-2]: 13-14*).

Regarding the free exercise of religion claim, the Appeals Court wrote:

> It is unclear on what basis LeVake argues that his right to free exercise of religion was violated. LeVake does not contend that respondents prohibited him from practicing the religion of his choice. He does not assert that respondents demanded that he refrain from practicing his religion outside of the scope of his duties as a public school teacher in order to retain his teaching position, and he does not assert that the curriculum requirements incidentally infringed on his religious practice.

Regarding the free speech argument, the Court supported the right of the district to determine curriculum, a position supported with abundant case law:

> The classroom is a "marketplace of ideas," and academic freedom should be safeguarded. But LeVake, in his role as a public school teacher rather than as a private citizen, wanted to discuss the criticisms of evolution. LeVake's position paper established that he does not believe the theory of evolution is credible. Further, LeVake's proposed method of teaching evolution is in direct conflict with respondents' curriculum requirements. Accordingly, the established curriculum and LeVake's responsibility as a public school teacher to teach evolution in the manner prescribed by the curriculum overrides his First Amendment rights as a public citizen. [Citations omitted.]

Regarding the due process claim, the Court wrote:

> The school board may regulate a teacher's speech in the classroom if it has provided the teacher with specific notice of what conduct is prohibited. LeVake's due process claim is premised on his belief that respondents deprived him of his liberty interest to teach his class free "from state action which impinges upon and violated his constitutional rights to free speech and free exercise" by failing to provide him with adequate notice of what types of expression were prohibited before reassigning him. The cases LeVake relies on in making this argument involve the termination of teachers, but LeVake was not terminated. In fact, he was not even demoted. Further, before accepting the position to teach tenth-grade biology, LeVake understood that respondents' prescribed curriculum included teaching students about evolution. LeVake was given sufficient notice about what he could and could not teach through the established curriculum and the syllabus. [Citations omitted.]

Concluding the decision, the Court wrote:

> Because LeVake's position paper and his statement to Hubert make it clear that LeVake would not teach the required course curriculum in the manner established by the school board, LeVake has not presented any genuine issue of material fact regarding his free exercise, free speech, and due process claims. Thus, the district court did not err in granting respondents' motion for summary judgment.

For the complete text of the decision, see <http://www.lawlibrary.state.mn.us/archive/ctappub/0105/c8001613.htm>.

UPDATES

Alabama: On February 8, 2001, the State Board of Education approved a new science curriculum, which improves treatment of evolution compared to the previous state requirements. The board took no action regarding the state's evolution disclaimer required in all biology textbooks.

Georgia: House Bill 391 was introduced in the state legislature in February 2001 and referred to the Education Committee. The bill was not taken up in committee before the legislature adjourned on March 21. This bill would have allowed teachers "to present and critique any and all scientific theories" about "the origins of life and living things, including the origins of humankind." It also encouraged teachers "to make distinctions between philosophical materialism and authentic science..." For the text of the bill, see <http://www.legis.state.ga.us/Legis/2001_02/sum/hb391.htm>.

Idaho: According to the *Moscow-Pullman Daily News* (January 28, 2001), several Idaho state legislators are planning again to review proposed K-8 assessment standards that include evolution before they come up for final approval. The standards have been adopted by the House Education Committee, but final legislative action will not come before next year. One representative was quoted as being concerned that the standards do not mention "alternate theories on the development of modern living creatures" and that students would begin instruction in evolution before the 6th or 7th grades.

Kansas: On February 14, 2001, the State Board of Education voted 7-3 to adopt new state science standards, returning evolution, the Big Bang, and other scientific concepts to Kansas classrooms. In August 1999, the previous board had removed evolution from the standards. The reversal of this action had been expected since the 2000 primary elections, when candidates who promised to return evolution to the standards defeated several previous board members. (*See* RNCSE *2000; 20 [3]: 4-6 and 20 [4]: 12.*)

Louisiana: House Bill 1286 was introduced in the state legislature in March 2001 and referred to the House and Governmental Affairs Committee. Although this bill does not explicitly mention evolution, creationism, or education, its language echoes that of anti-evolution bills in other states. The abstract of HB 1286 reads: "Prohibits any branch, department, agency, official, employee, or other entity of state government or political subdivision from knowingly printing or distributing material that contains information that is false or fraudulent and provides for recovery of costs upon a violation." The key phrases in the bill that suggest that it may be intended, at least in part, to inhibit evolution education prohibit "knowingly" printing or distributing "any material that contains, or presents as factual, information which has been proven to be false or fraudulent." The term "false or fraudulent information" is becoming popular among opponents of evolution. At the time of writing, this bill has not yet been taken up in committee. For the current status and text of HB 1286, see <http://www.legis.state.la.us/bills/byinst.asp?sessionid=01RS&billtype=HB&billno=1286>.

Louisiana: House Concurrent Resolution 74 was introduced in the state legislature in April 2001 and referred to the Education Committee. As introduced, this resolution opposed racism. It then asserted that Charles Darwin and his books promoted the justification of racism, and that Adolf Hitler ultimately exploited these same views to justify killing millions of people. In addition, the resolution deplored and rejected "... the core concepts of Darwinist ideology that certain races and classes

of humans are inherently superior to others...." It is commonly claimed by some creationists that Darwin and/or acceptance of evolution are responsible for essentially all the ills (real and supposed) of modern society, from Marxism to fascism, from racism to eugenics, from abortion to feminism, from homosexuality to school shootings. It is ironic in this case that Darwin, and his extended family, had very progressive views on race for their day and were fervent opponents of slavery. The sponsor of HCR 74 was quoted in a newspaper story as suggesting that a disclaimer for textbooks discussing evolution could be the next step following this resolution. On May 1, the Education Committee considered the resolution, and after a one-hour hearing voted 9-5 to recommend passage to the full House. The proposed resolution provoked considerable discussion in the Louisiana press and was labeled "weird" by Governor Mike Foster, speaking to a convention of reporters. On May 8, HCR 74 was considered in the House of Representatives. By a vote of 65-28 the House adopted an amendment that removed all mention of Darwin and Darwinism, leaving a straightforward condemnation of racism. The resolution was then passed without objection and sent to the Senate. For the current status and text of HCR 74, see <http://www.legis.state.la.us/bills/byinst.asp?sessionid=01RS&billtype=HCR&billno=74>.

Michigan: House Bill 4382 was introduced in the state legislature in February 2001 and referred to the Education Committee. As of this writing, a hearing in committee is not expected in the near future. HB 4382 would revise Michigan's curriculum content standards to indicate that evolution and natural selection are "unproven theories". In addition, it provides that, along with those "unproven theories", students should be taught "... the theory that life is the result of the purposeful, intelligent design of a creator". Among the ten co-sponsors of this bill are four members of the Education Committee, including its chair. To see the status of this bill and links to its text, see <http://michiganlegislature.org/isapi/nls_ax.dll/BillStatus?LegSession=2001-2002&DocType=HB&BillNum=4382>.

Michigan: House Bill 4705 was introduced in the state legislature in May 2001, cosponsored by four Education Committee members, and referred to the Education Committee. As of this writing, the bill has not been heard in committee. The complete text of HB 4705 reads: "Sec. 1164. (1) 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. (2) As used in this section: (A) "design hypothesis" means the theory that life and its diversity result from a combination of chance, necessity, and design. (B) "Methodological naturalism" means the theory that nature is all there is and that all phenomena, including living systems, result only from chance and necessity."

Montana: House Bill 588 was introduced in the state legislature in February 2001 and referred to the State Administration Committee. On February 19, it was heard in committee and tabled by a 14-4 vote. The bill would have required, among other things, the teaching of "competing theories of origin" rather than "the exclusive teaching of the theory of evolution"; a "reasonably balanced presentation" of evidence "supporting and disproving each major theory of origin"; and the appointment of a volunteer citizen panel, with "supporters and nonsupporters of Darwin's theory of evolution" equally represented, to recommend instructional materials "that comply with the intent" of the bill. For the text of the bill, see <http://data.opi.state.mt.us/bills/2001/billhtml/HB0588.htm>.

Virginia, Culpeper: An organization called Family/Government/Church Inc has announced "a statewide campaign to combat the evolution theory being taught in the Virginia public schools". They have produced an "insert" for students to place in biology textbooks "... in order to remind them that evolution is not a fact, it is not even a legitimate scientific theory but is really only a belief based primarily on anti-Christian concepts." The insert itself emphasizes differences between what it refers to as "MICRO evolution" and "MACRO evolution".

Washington: Senate Bill 6058 was introduced in the state legislature in February 2001 and referred to the Education Committee. The bill would require "all science textbooks purchased with state moneys" to contain an evolution disclaimer very similar to that required in Alabama since 1995. The bill was not taken up in committee before the legislature adjourned its regular session on April 22. For the text of the bill, see <http://www.leg.wa.gov/wsladm/billinfo/dspBillSummary.cfm?billdir=6050-6074&billnumber=6058>; Pacific Northwest Skeptics organized opposition to the bill at <http://www.eskimo.com/~pierres/6058.html>.

West Virginia: House Bill 2554 was introduced in the state legislature in February 2001 and referred to the Education Committee. The bill did not come up in committee before the legislature adjourned on April 14. The title of the bill explains its purpose as "Providing for the teaching of creation science and evolution science on an equal basis in the public schools." The bill may be downloaded from <ftp://129.71.161.247/ftp-house01/HB2551-2600/hb2554%20intr.wpd>.

[NCSE thanks Gary Bennett, Robert Collins, Bonnie Dixon, Marjorie Esman, Greg Forbes, Barbara Forrest, Ann Mulligan, Sarah Pallas, and Pierre Stromberg for information used in this report.]

NCSE NEWS

News from the Membership

Glenn Branch
NCSE Office Manager

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

The third edition of **Philip Appleman**'s anthology *Darwin* (New York: WW Norton, 2001) is now available; on the back cover, Stephen Jay Gould describes it as "[t]he best Darwin anthology on the market". Among the members, supporters, and friends of NCSE who are represented in Appleman's book are Niles Eldredge, Stephen Jay Gould, Molleen Matsumura, Betty McCollister, Thomas McIver, Kevin Padian, Michael Ruse, Eugenie C Scott, Thomas J Wheeler, and George C Williams. The text of NCSE's pamphlet "Seven significant court decisions regarding evolution/creation issues" is also included. Look for John Greene's review of *Darwin* in a future issue of RNCSE.

In his Salon article "Assault on evolution" <http://www.salon.com/books/feature/2001/02/28/idt/index.html>, **Larry Arnhart,** Professor of Political Science at Northern Illinois University and author of *Darwinian Natural Right: The Biological Ethics of Human Nature* (Albany: SUNY Press, 1998), explains that the proponents of intelligent design creationism are "fighting a dishonest battle for a theory that has little empirical support." In another recent article, "The truth, goodness, and beauty of Darwinism" (*Zygon* 2001 Mar; 36 [1]: 77–92), Arnhart writes that "as a young proponent of 'creation science,' I rejected Darwinian biology as false, bad and ugly. Now I defend Darwinism as true, good, and beautiful. Moreover, I now see Darwinism as compatible with the natural piety that arises as one moves from nature to nature's God."

Marshall Berman, one of NCSE's 1999 Friend of Darwin awardees (*see* RNCSE *2000; 20 [1–2]: 22*), was presented with his Friend of Darwin award at a meeting before the New Mexico State Board of Education, of which he is a member. The president of the board, Flora Sanchez, commented that it was very inspiring for the other board members to see such an award presented to one of their own for his effective work. Berman is also the founding president of New Mexico's Citizens for Excellence in Science Education. [*Thanks to M Kim Johnson for the news.*]

Tim M Berra, Professor Emeritus of Evolution, Ecology, and Organismal Biology at the Ohio State University at Mansfield and author of *A Natural History of Australia* (San Diego: Academic Press, 1998), was awarded research grants totaling nearly $10 000 from the National Geographic Society and the Columbus (Ohio) Zoo Conservation Fund to study the life history of nurseryfish, *Kurtus gulliveri*, in Australia's Northern Territory. Berra's excellent primer *Evolution and the Myth of Creationism: A Basic Guide to the Facts in the Evolution Debate* (Stanford: Stanford University Press, 1990) is still in print. [*Thanks to Andrew O Lutes for the news.*]

Martin Czigler was startled to read an enthusiastic blurb for Phillip E Johnson's collection of essays *Objections Sustained* (Downers Grove [IL]: InterVarsity Press, 1998) in the computer trade magazine *InfoWorld* on May 14, 2001. He wrote,

> I was dismayed that you gave a free plug to Phillip E Johnson's book. ... The comment by Nicholas Petreley shows that he doesn't understand what the theory of evolution is. It is no more a "materialist dogma" than the theory of plate tectonics, or stellar lifetimes, or any other science that deals with events in the past.
>
> Johnson presents legalistic — not scientific — arguments in his writings, and he doesn't present any alternative theories of his own. At the same time, his "Intelligent Design" theorists have failed to explain numerous examples of incompetent design. For example, humans lack the

The New Mexico State Superintendent of Public Education, Michael Davis, and the New Mexico State Board of Education President, Flora Sanchez, congratulate NCSE member Dr Marshall Berman at a meeting before the Board for receiving the NCSE Friend of Darwin Award (being held up by Dr Berman). Photograph: M Kim Johnson.

ability to synthesize vitamin C because of a defective gene, a "design feature" that we share with other primates, but not with most other mammals.

Here's a quote from one of Johnson's lectures: "It's a great time to be a young Christian who is excited about using his or her mind in the service of the Lord, because we will discover that 'in the beginning was the Word' is fact not fantasy. It's as true scientifically as it is spiritually or Biblically or whatever." I'd like to see the peer-reviewed scientific paper that demonstrated this!

These religious beliefs don't belong in science classes, nor do they belong in *InfoWorld*. Petreley ought to stick to Linux.

Czigler's letter was published on May 28.

In "Darwin in mind: 'Intelligent design' meets artificial intelligence" (*Skeptical Inquirer* 2001 Mar/Apr; 25 [2]: 35–9), **Taner Edis** criticizes William Dembski's anti-evolutionary arguments from information theory. Summarizing his article, Edis writes, "What, then, are we to make of ID? It now seems like a bad argument, concocted of pointless complaints against evolution on one hand and flawed intuitions about information and intelligence on the other." Edis's most recent article for *RNCSE* was "Cloning creationism in Turkey" (*RNCSE* 1999; 19 [6]: 30–5). Also of interest in the same issue of *Skeptical Inquirer* are David Roche's "A bit confused: Creationism and information theory" (40–2), Matt Young's review of old-earth creationist Hugh Ross's *The Genesis Question* (51–2), James C Sullivan's review of NCSE Supporter Niles Eldredge's *The Triumph of Evolution and the Failure of Creationism* (53–4), and Susan Bury's "How to live with evolution" (56–7).

George Erickson's *True North: Exploring the Great Canadian Wilderness by Bush Plane* — "an adventure-filled, pro-environment, pro-science tour of northern Canada and Alaska" — was published in September 2000 by Thomas Allen & Son, Ltd. "When appendicitis, loss of employment, and a threatened divorce remove three flying friends from a long-planned flight to Alaska, the author sets off on his own. With the aid of his seaplane, the Tundra Cub, he dips a wing to polar bears, is surrounded by musk ox and caribou herds, searches the barrens for clues to the disappearance of a long-missing priest, and measures the earth like Eratosthenes on the edge of an arctic sea."

Surfing the Web in search of information about the Cambrian Explosion, **Lance Flitter** ran across what seemed to be a useful science education web site — until he realized that its evolutionary biology section contained numerous links to anti-evolutionary and pseudoscientific web resources. After an extensive e-mail correspondence with the webmaster — in which he debunked the all-too-familiar litany of excuses, such as "evolution is just a theory", "evolution is a theory in crisis", "it is only fair to teach both sides", and "evolution is antireligious" — Flitter succeeded in having the links replaced with links to legitimate scientific information about evolution.

John J Flynn, MacArthur Curator of Geology at the Field Museum and Associate Chairman of the Committee on Evolutionary Biology at the University of Chicago, was awarded a John Simon Guggenheim Memorial Foundation Fellowship for 2001 to study the interplay of evolution and geologic change in South America.

Long-time NCSE member **Laurie Godfrey** is teaming up with NCSE's editor **Andrew Petto** to edit a revised and updated version of the classic *Scientists Confront Creationism* (New York: WW Norton, 1983). Isaac Asimov described the original version, edited by Godfrey, as "[a] badly needed overview of the scientific view of evolution, explaining clearly and straightforwardly exactly what scientists think and why." The new edition will contain contributions by a number of NCSE members and supporters, including John R Cole, Brent Dalrymple, Niles Eldredge, Eugenie C Scott, Ronald Numbers, Kevin Padian, Robert Pennock, and Victor Stenger. Look for it to appear in 2002.

Andrew O Lutes continues to defend evolution enthusiastically in the letters-to-the-editor section of his local newspaper. Responding to a letter that cited the eye — presumably the vertebrate eye — as an instance of "irreducible complexity", Lutes wrote, "Anti-evolutionists, who must think Exodus 20:16 doesn't apply to them, misquote Chapter 6 of Darwin's *On the Origin of Species* about the eye's supposed[ly] impossible evolution. The entire passage, if quoted, shows what's actually said is that, although eye evolution seems impossible, research shows that it can occur" (Mansfield, Ohio, *News-Journal*, August 7, 2000). The biblical reference, by the way, is to the injunction against bearing false witness.

Adrian Melott, Professor of Physics and Astronomy at the University of Kansas, discussed "Darwinism vs Intelligent Design" with William A Dembski on KERA's Glenn Mitchell show on May 1, 2001. He reports that on the show, Dembski cited Stuart Kauffman (author of *The Origins of Order*, *At Home in the Universe*, and, most recently, *Investigations*) as one example of a mainstream scientist who supports intelligent design. Informed by e-mail of his appropriation by the intelligent design movement, Kauffman wrote, "my own books explore self organization in complex systems and the implications for the origins of life and evolution and ontogeny. I am, however, a Darwinian in the broad sense and hold to the view that mutations are random with respect to prospective adaptive significance. Hence I hold no truck with intelligent design." He added, "it is

fine with me if you publicize my response. We have to fight creationism everywhere it pops up." Although the show is not available on line, tapes can be obtained for $10.00 from KERA, Attn: Glenn Mitchell Show, 3000 Harry Hines Boulevard, Dallas TX 75201.

Just as this issue of *RNCSE* went to press, it was announced that **Adrian Melott** was awarded the Steeples Service to Kansans Awards by the University of Kansas. The Steeples Award, in its 4th year, recognizes faculty in the College of Liberal Arts and Sciences who provide significant service to the people of Kansas as a purposeful extension to their teaching and research. Raymond Ammar, chair of the University of Kansas's Department of Physics and Astronomy, where Melott has taught since 1986, said that Melott had served Kansans through his talks and visits at schools, churches, and civic organizations around the state. "He had a major role as an organizer of Kansas Citizens for Science, which was of crucial importance in restoring Kansas's public school science standards and with it the reputation of the state", Ammar commented.

Philo, the official publication of the Society of Humanist Philosophers, devoted much of a recent issue (2000 Fall-Winter; 3 [2]) to discussing methodological naturalism, intelligent design creationism, and the fine-tuning argument for the existence of God. NCSE members were well represented. **Keith M Parsons**, *Philo*'s editor, introduced the issue with his editorial "Defending naturalism" (3-6); **Barbara Forrest**, a recipient of NCSE's Friend of Darwin award, contributed "Methodological naturalism and philosophical naturalism: clarifying the connection" (7-29); **Theodore M Drange** wrote on "The fine-tuning argument revisited" (38-49); **Victor J Stenger** presented "Natural explanations for the anthropic coincidences" (50-67); and **Mark I Vuletic** reviewed Michael J Denton's *Nature's Destiny: How the Laws of Biology Reveal Purpose in the Universe* (89-103). Also of interest was Theodore Schick Jr's "Methodological naturalism vs methodological realism" (30-7), which argues against both Eugenie C Scott's and Philip Johnson's views about methodological naturalism.

The headline announced "Author speaking to Notre Dame community to question evolution" (*The* [Notre Dame] *Observer*, September 21, 2000). Was it Duane Gish? Was it Phillip Johnson? No — it was **Robert Pennock**, NCSE member and author of *Tower of Babel: The Evidence Against the New Creationism* (Cambridge [MA]: The MIT Press, 1999), who spoke in South Bend on that day. His lecture was entitled "Should evolution be taught in the public schools? What Dorothy learned when the creationist whirlwind hit Kansas". Contrary to the headline's implication, Pennock affirmed that evolutionary theory is overwhelmingly supported by the scientific evidence and that teaching it is essential. His talk focused on "the fairness question" and rebutted the argument of Notre Dame philosopher Alvin Plantinga, who has argued that teaching evolution violates (what Plantinga says is) a basic right of parents not to have their children taught beliefs that contradict their own comprehensive beliefs, including what they know as Christians. Pennock explained why teaching evolution but excluding creationism is actually the fair and just approach, so long as evolution is taught scientifically and not dogmatically. He also referred to theologians who say that evolution is at odds with neither religion in general nor Catholicism in particular, noting that "Both Pope John Paul II and Pope Pius XII made statements that said that there was no conflict" (*The* [Notre Dame] *Observer*, September 22, 2000). Creationism's appeal is not scientific, he suggested, but primarily existential: creationists are convinced that evolution robs life of morality and meaning (see his "Naturalism, creationism, and the meaning of life: the case of Phillip Johnson revisited", *Creation/Evolution* 1996 Winter; 16 [2] nr 39: 10-30). On the contrary, he concluded, evolution provides a view of life that, as Darwin said, is full of grandeur. The lecture was sponsored in part by the Notre Dame/Saint Mary's chapter of Sigma Xi, The Scientific Research Society; Sigma Xi named Pennock a national distinguished lecturer for 2000-2002. Pennock is an associate professor of philosophy at Lyman Briggs School at Michigan State University. His new anthology, *Intelligent Design Creationism and its Critics*, will be published by the MIT Press in 2001.

J William Schopf, director of the Center for the Study of Evolution and the Origin of Life at UCLA, was honored by the Phi Beta Kappa Society for his book, *Cradle of Life: The Discovery of Earth's Earliest Fossils* (Princeton: Princeton University Press, 1999). At the Phi Beta Kappa Senate banquet, held in Washington DC on December 1, 2000, Schopf received $2500 and spoke briefly about his prizewinning book, which, in the words of *Nature*'s reviewer, "tells his own story of how earth's early microbial biosphere was discovered".

Just across the Ohio River from Answers in Genesis, **Steve Schubart** and Jim Lytle — both committed Christians with scientific training — wrote the following letter to the editor of the Cincinnati *Enquirer*, which was published on December 20, 2000:

> The organization building the "creation science" museum in Kentucky expresses its basic principle that the Bible and science are in conflict. It may come as a surprise that some of us are committed to both faith in God and knowledge of science.
>
> The fabricated disagreement between faith and science is neither necessary nor helpful. While it is impossible for either religious interpreters or scientists to know all the answers as God does, the truth of science and the

> Bible are not mutually exclusive. However, some Bible interpreters as well as some scientists are blatantly in error, because there are more accurate understandings for both that are not in conflict. Conversely, some scientists and Bible interpreters are correct. Instead of defending the Bible out of fear in such a way as to promote conflict, we believe it is better to understand it with as much conformity to scientific discoveries as possible. Unknowns can remain uncharted with no harm to either faith or science. A noted theologian forcefully states, "We know, in fact, that truth cannot contradict truth."

Although Answers in Genesis typically uses the worldwide forum of its web site to perpetrate the latest young-earth creationist misinformation, the daily news article on December 26, 2000, was instead wholly devoted to attempting to rebut Schubart and Lytle's letter (see <http://www.answersingenesis.org/docs2/4418news12-26-2000.asp>). Why was AIG's staff so defensive? Schubart speculates that "their financial support would crumble if their donors realized how off-base the theology is."

Remember the Islamic creationist screed *The Evolution Deceit*, written by the pseudonymous Harun Yahya? (*See* RNCSE *1999; 19 [6]: 15-7, 18-20 and 25-9, and 30-5 if not.*) It was extravagantly praised by the anonymous reviewer in *The Minaret* (2000 Sep; 39), which bills itself as America's source on Islam. Fortunately, **Tufail Shanavas** quickly replied, describing in detail how *The Evolution Deceit* is "a fundamentalist Christian fraud, under the cover of Islamic veil, that misrepresents Islam and the Quran" (*The Minaret*, 2000 Nov/Dec; 36-7). Shanavas's article "Islam does not inhibit science" appeared in *RNCSE* 1999; 19 (6): 36-7, 45.

Niall Shanks and Karl Joplin, whose "Of Mousetraps and Men: Behe and Biochemistry" appeared in *RNCSE* 2000; 20 (1-2): 25-30, continue their critique of Michael Behe in their "Behe, biochemistry, and the invisible hand," *Philo* 2001 Spring-Summer 2001; 4 (1), 54-67, and on line at <http://www.philoonline.org/library/shanks_4_1.htm>. They conclude, "it is simply wrong to suggest that there is no possible unguided, naturalistic explanation of irreducible complexity ... If Behe wishes to disagree, he would do well to formulate precise and unambiguous answers to the intelligent design questions we have proposed, and then to justify his answers about the identity, methods, and materials of his hypothetical designer with the provision of high-quality evidence."

NCSE Supporter **James W Skehan SJ** just published *Roadside Geology of Massachusetts* (Missoula [MT]: Mountain Press, 2001), which, in the words of its publisher, "explains the geologic history behind the rocks and landforms visible from the state's highways, including such well-known historic features as Bloody Bluff, Beacon Hill, Plymouth Rock, and Walden Pond. Interspersed through the guide book are tales of pioneering geologists such as Harvard's Louis Agassiz, the first to propose that continental glaciers — not the remnants of Noah's Flood as early settlers had imagined — polished the state's bedrock and deposited its enormous boulders and sand plains." Skehan is professor emeritus in the Department of Geology and Geophysics at Boston College and director emeritus of Weston Observatory.

Paul K Spudich was elected a Fellow of the American Geophysical Union, an honor bestowed on 0.1% of the membership each year, "for innovative work in understanding earthquake source processes and scattering phenomena." (Information about the AGU's awards is available on its web site at <http://www.agu.org/inside/insidaguhn.html>.)

Victor Stenger, retired Professor of Physics and Astronomy at the University of Hawaii at Manoa, recently published a new paper on the Secular Web entitled "Intelligent design: The new stealth creationism", in which he extensively criticizes the arguments of William Dembski, Hugh Ross, and William Lane Craig. The paper, to be found at <http://www.infidels.org/library/modern/vic_stenger/stealth.pdf>, is in Adobe PDF format and can be read using the free Adobe Acrobat Reader.

"A modern earth narrative: What will be the fate of the biosphere?", by **Richard S Williams Jr**, appeared in *Technology in Society* 2000; 22: 303-39. In his article, Williams argues that the failure of humans to comprehend what he calls "the Earth Narrative" — which is based on the concepts of deep time and biological evolution — is likely to have disastrous consequences for the biosphere. Williams is a senior research geologist with the US Geological Survey and a vice chairman of the National Geographic Society's Committee for Research and Exploration.

Brad Williamson is the new president-elect of the National Association of Biology Teachers. His term of office began on January 1, 2001. Williamson has taught biology in suburban Olathe, Kansas, for the past 11 years; his op-ed piece about the furor over the Kansas state science standards appeared in the Washington *Post*. He is also the cofounder of the Monarch Watch, a collaborative effort to study the biology of the monarch butterfly migration phenomenon.

When a creationist wrote to the Milwaukee *Journal Sentinel* to claim that evolution is "just a theory" and to chide the newspaper for reporting on it matter-of-factly, not one but two NCSE members responded in the June 10, 2001, issue. **John Zimny** ironically asked why the National

Academy of Sciences, the American Association for the Advancement of Science, and the journals *Nature* and *Science* have all failed to realize that evolution is flawed. He also noted that, contrary to the creationist's claim, the theory of evolution is eminently falsifiable. **Bill Castagnozzi** explained that the theory of evolution is supported by overwhelming evidence from a variety of scientific fields. He concluded by describing creation science as "a poorly constructed sand castle drying in the sun. Any attempt to examine its structure results in nothing more than grains coursing through one's fingers."

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

Citizens Group Receives ACLU Award

Molleen Matsumura
Faith Network Project Director

On November 18, 2000, at an annual Bill-of-Rights dinner, the American Civil Liberties Union in Washington State presented a Civil Libertarian Award not to one person but to an entire group — the Burlington-Edison Citizens for Science Education (BECSE). The ACLU cited BECSE "for courageous and persistent efforts to keep religious teachings out of the Burlington-Edison High School." In its press release about the award, the Washington ACLU explained, "Several years of persistent and savvy organizing paid off when the group convinced the school district to keep the biology class focused on scientific theories, not religious doctrines."

When NCSE member Ken Atkins, Syd Harris, and other citizens learned that high school science teacher Roger DeHart had been teaching "intelligent design theory" for years, they began their own years-long effort to rectify the situation (*see* RNCSE *1997; 17 [4]: 7, 8; 18 [1]: 9; 1998; 18 [3]: 6; 1999; 19 [1]: 6-8; 1999; 19 [3]: 6-7; 1999; 19 [6]: 9-12*). When DeHart stated that no students had complained, students stepped forward who explained that their complaints in the classroom had been ignored. When board of education members discussed backing DeHart, Atkins contacted NCSE.

Atkins, Harris, and others formed the BECSE and went to work to keep fellow citizens, their board of education, and the school administration informed about the issues. They wrote editorials, appeared at school meetings, provided necessary information to the ACLU, and carefully explained the scientific issues to the administration with information gathered from NCSE, ACLU, and their own independent research. BECSE monitored supplementary materials considered for use in DeHart's classes, and when these materials were unscientific (for example, when there was a proposal to substitute "irreducible complexity" literature for "intelligent design theory"), they notified administrators.

Atkins, who accepted the award on behalf of BECSE, stressed the importance of cooperative efforts, thanking the ACLU and cooperating attorney Rich Berley, fellow NCSE member Pierre Stromberg (whose website BECSE used as a resource), and NCSE. He reiterated the value of teamwork when he wrote to NCSE:

> Stepping into a public role is not easy, it's actually a bit scary, but the support from so many eased the uncertainty. The Washington ACLU, the NCSE, and the thousands of citizens in Skagit County who signed their names to our petition in the local papers, who wrote letters to the editor, and who gave all of us a phone call of support, passed on a new source of information, or slapped us on the back, deserve a thank you. For the Burlington-Edison Committee for Science Education to be recognized with this award is a real honor. Hopefully, our whole community will take pride in it.

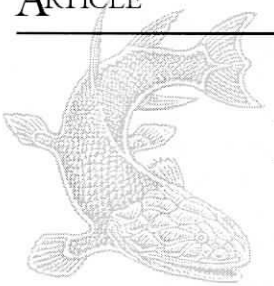
The many NCSE members who helped BECSE (*see box below*) can take pride, too.

Partnerships Promote Success

As Ken Atkins pointed out when accepting the award on behalf of Burlington-Edison Citizens for Science Education, cooperation among a number of individuals and organizations greatly enhances efforts to defend evolution education. When he called on NCSE for help, a number of NCSE members in Washington stepped forward. They include Val Mullen, David Milne, and Pierre Stromberg.

Stromberg's Paranormal Northwest web site, <http://www.eskimo.com/~pierres/>, has also been a resource to members outside the state. The site contains information on a number of pseudoscientific topics. Resources concerning creationism include a "Creationism Atlas of Washington State" and a detailed discussion of some creationists' claims that the "knee" of the famous "Lucy" hominid was found at a great distance from the rest of the skeleton.

Other NCSE members contribute to websites of several organizations combating creationism, including those of Kansas Citizens for Science <http://www.kcsf.org>, New Mexicans for Science and Reason (see especially the creationism links at <http://www.nmsr.org/srchnmrs.htm>), and the extensive creation/evolution resources of the talk.origins archive at <http://www.talkorigins.org/>.



Creationism and the Emergence of Animals: The Original Spin

Nigel C Hughes
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In 1999 I attended a meeting near Chengjiang, China on "The Origins of Animal Body Plans and Their Fossil Records" (Chen and others 1999). The meeting was held near Chengjiang because there are fantastic fossils of Early Cambrian animals in the area. What makes these fossils remarkable is that they not only preserve the hard, skeletonized parts of animals, but also contain replicas of the external form of their soft parts. Such sites of such "exceptional preservation" are rare, but are enormously important scientifically for the glimpses they give us of the panorama of early animal life (Gould 1989; Conway Morris 1998).

Although the meeting was billed as a scientific conference, a number of anti-evolutionists were also in attendance, including several people associated with the Center for the Renewal of Science and Culture (CRSC), the creationist arm of the Discovery Institute, a Seattle-based organization that advocates "intelligent design" as an explanation for biotic diversity. Indeed, one of the principal organizers of the meeting was Paul Chien, a marine toxicologist at the University of San Francisco in Santa Rosa, California, and a senior fellow of the CRSC.

The talks were scheduled to provide prominent slots for CRSC fellows and their associates. Even more troubling was the fact that scientists were not informed of the involvement of the CRSC before arriving at Chengjiang and only became aware of its involvement once they inspected the printed abstracts of the presentations. Many scientists are becoming concerned about the activities of the CRSC, and so it seems important to clarify what occurred at this conference.

My experience at the meeting convinces me that all the anti-evolutionists who attended were motivated by political, not scientific, interests. There is nothing inherently wrong with that, of course, although it is markedly unusual in a *scientific* conference. I even had to admire the nerve of several anti-evolutionist speakers who made presentations in front of opponents as formidable as Eric Davidson, the developmental biologist from the California Institute of Technology and a member of the US National Academy of Sciences. Nevertheless, I could find nothing in any of their presentations that provided *scientific* evidence suggestive of the action of an intelligent designer, undiscovered natural laws that govern the development of form, or the action of some unspecified principle of "harmony" that drove the early evolution of animals.

What *was* presented were old Paleyian arguments for design cast up in a variety of molecular guises. These arguments are based on the notion that, because we do not currently understand *all* aspects of the evolution of life, evolutionary ideas must be fundamentally flawed and, therefore, there must be an intelligent designer. Rather than presenting a coherent argument for the action of an intelligent designer, these advocates were more interested in exploring what they present as weaknesses in evolutionary thinking. Their position ignores the colossal amount of concordant evidence supporting evolution and refuses to acknowledge the legitimate complexity of modern evolutionary thinking.

Unlike the contingent of scientists, the anti-evolutionists at the meeting all appeared to have known of the CRSC's involvement with the meeting before their arrival. These anti-evolutionists represented a broad range of anti-evolutionary viewpoints. At one extreme their camp included Michael Denton, a senior fellow of the CRSC, whose professed "pagan" personal philosophy, as he explained it to me, seemed about as far from biblical literalism as one could imagine. At the other extreme there was a young, fervently Christian student who spoke candidly of his belief in young-earth creationism. Denton is a qualified geneticist, and I could trace no scientific or philosophical link between his platonic notions of natural laws that govern the form of animal archetypes and the strict biblical-literalist, young-earth stance espoused by the student.

The fact that both these individuals claimed that the Discovery Institute had financially supported their attendance at the meeting suggests that the Institute's involvement in the meeting was not motivated primarily by the desire to present a coherent scientific argument for "intelligent design". Rather, it suggests that the Discovery Institute was more interested in supporting any views that appear to challenge evolutionary explanations,

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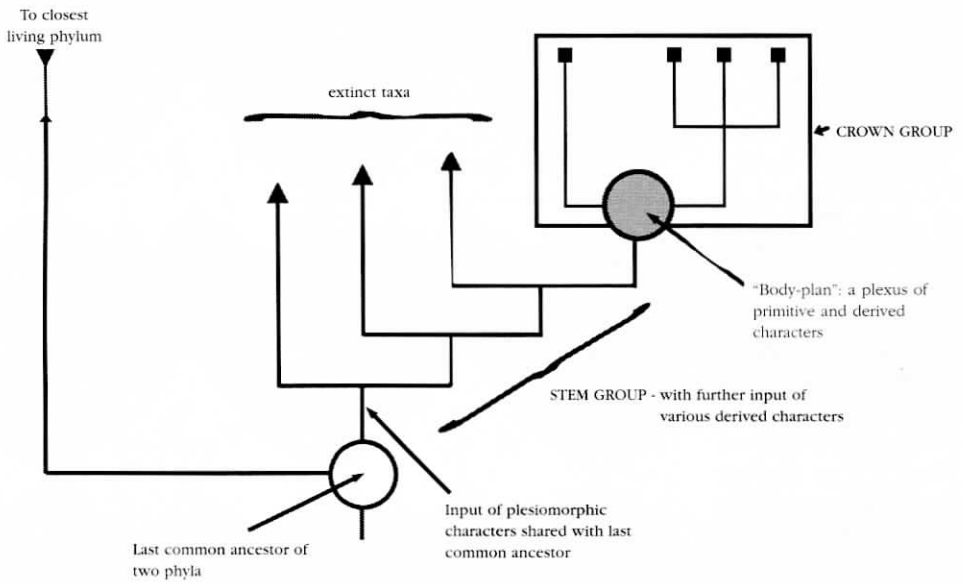

Figure 1. *How to build a phylum. (See the text for further explanation.) Redrawn by Janet Dreyer, with modifications, from: Budd G, Jensen S. A critical reappraisal of the fossil record of the bilaterian phyla.* Biological Reviews *2000; 75: 253-295; Fig. 1.*

regardless of whether these views are mutually exclusive.

Although I cannot read the minds of the individuals associated with the CRSC, I can advance a reasoned interpretation of what might be motivating their interest in this issue. The US Supreme Court ruled in *Edwards v Aguillard* (1987) that creationism cannot be taught in science classes in public schools because it is not a scientific concept and because there is no secular purpose in teaching it. Advocates of intelligent design creationism (IDC) may attempt to circumvent this ruling by arguing that "intelligent design" is a *scientific* alternative to evolution. Tactics for doing so might include having IDC representatives speak at scientific meetings alongside recognized scientists and having their ideas published alongside scientific papers in conference proceedings.

The association of "intelligent design" with legitimate scientific conferences and publications could be presented to US lawmakers as evidence that advocates of IDC are pursuing reputable science rather than sectarian politics, and that the scientific community accepts "intelligent design" as a viable and productive topic of study. This in turn would support the recent debate about "alternatives to evolution" to public school science classes. The remainder of this article seeks to identify specific positions that those associated with the Discovery Institute appear to take with regard to scientific evidence on this matter, and then respond to these positions from my own viewpoint as a scientist.

Why Anti-evolutionists Focus on the Origin of Animals and The "Cambrian Explosion"

It seems likely that the origin of animals will remain a favorite subject for anti-evolutionists over the coming years. Before reviewing the current scientific evidence concerning the origin of animals, I wish to outline the strategic position of IDC anti-evolutionists — especially those associated with the CRSC — with regard to the origin of animals as far as I understood it from the meeting.

IDC advocates claim that: 1) The major groups of animals had separate, independent origins (by "major groups of animals", anti-evolutionists mean the marine creatures without backbones that commonly correspond to the "invertebrate phyla" such as Mollusca, Brachiopoda, Arthropoda, and so on ... in addition to the first chordates). This position, of course, denies common ancestry among living taxa. 2) These major animal groups originated over a "very short" interval of geological time associated with the "Cambrian explosion" (some IDCs suggest a period of 2–3 million years). This is much shorter, of course, than expected by most evolutionary models.

These two points lead to the conclusion that the rate and magnitude of innovation were far too high to be accounted for by natural selection and can only be explained as the actions of a designer.

The IDC position is challenged by the scientific facts. The claim that the major groups of animals appear suddenly in the fossil record is easily demonstrated as incorrect by the extensive fossil record of early animal evolution that stretches back several tens of millions of years earlier than the Chengjiang fossil beds. So anti-evolutionists are in deep denial of the fossil record when they cite the impossibly short interval during which new taxa emerged.

The claim that the major animal groups originated separately and independently is equally weak. The origin of animals took place relatively late in the earth's 4.6-billion-year history; however, recent fossil discoveries contain evidence of a long and rich ancestry for animal phyla. Of course, when most people think of the "major groups" of animals, they envision the vertebrate classes that represent what they think of as "animals" today — mammals, reptiles, amphibians, fishes, and birds. Vertebrates represent only some of members of one phylum — the Chordata. There are numerous other phyla, represented by such disparate creatures as starfish (phylum Echinodermata), spiders and crabs (phylum Arthropoda), clams and snails (phylum Mollusca), and many others.

In a broad sense each different phylum has a distinctly different fundamental structure and development — and each represents a different "body plan", or set of "body plans". Scientists understand body plans to refer to the major features of adult bodies in metazoans and/or of the developmental trajectory that gives rise to the adult body. Different body plans are distinguished on the basis of variation in features such as aspects of skeletal construction, symmetry, internal body cavities, segmentation patterns, and appendage structure.

Almost all metazoan phyla can be instantly distinguished from one another on the basis of variation in these fundamental features. The animal taxa that emerged out of the Precambrian are clearly related to living taxa, but even the early chordates — the founding members of the phylum that would later give rise to the vertebrates — bore little superficial resemblance to the vertebrates that would finally appear 100 million years later.

The IDC conclusion that the Cambrian Explosion can be explained only by reference to an intelligent designer is unsupported by the scientific evidence, as discussed below. Moreover, the common anti-evolutionist strategy of quoting Darwin as if science has stood still since he wrote *On the Origin of Species* backfires. One of the most remarkable aspects of the *Origin* is the way in which Darwin identified potential criticisms of his theory and addressed them with refreshing honesty. He was very frank about what he thought was the absence of fossils in rocks older than those bearing the oldest skeletonized fossils known in Europe (now known to be about 525 million years old), recognizing this absence as a "valid argument against the views here entertained" (Darwin 1859 [1964: 308]). After admitting that he had no solid explanation of the absence of these fossils, Darwin advanced some hypotheses about the incompleteness of the geological record. It is instructive to compare what we now know about the early history of life on the planet with what was known in Darwin's time and to ask how his views have stood the test of time.

The Scientific Issues Relating to the Origin of Animals and the Cambrian Explosion

What defines an animal, and how are different animal groups related?

The time around the Precambrian-Cambrian transition is important because it provides us with the first fossilized record of metazoans — multicellular animals with features such as differentiated organs and tissues — about 544 million years ago. I emphasize that "appearance" is not the same thing as "origin". There are myriad reasons related to the preservation and recovery of fossils that can explain why the first recorded appearance of a particular group can occur substantially after its evolutionary origin. The origin of animals is a complex issue for which several independent lines of evidence need to be investigated.

First, we need to decide what it actually is to be an animal. To do so, we must identify unique characters that are shared by all animals and distinguish them from other types of organisms. These are the characters that diagnose animals as a natural group and are considered ancestral for all animals. Once we have done that, we can proceed to identify other novel characters that distinguish specific subgroups (or "clades") of animals from the ancestral state and from each other. This process of distinguishing groups within groups produces a hierarchical nested set of related animals.

Animals are multicellular organisms that have cells specialized to perform particular functions; these cells are held together by an organic glue called extracellular matrix (ECM). On the basis of these features, biologists have long inferred that all animals constitute a natural group and evolved from a single common ancestor. But multicellularity with specialized cells is a general similarity — one that applies to some organisms, such as trees, that we would all agree are *not* animals — so multicellularity with specialized cells is not enough to prove common ancestry of all animal taxa. These features may have evolved independently in different lineages of single-celled organisms, and so it is the highly specific shared features, such as the nature of ECM, that assume a special significance for defining what it means to be an animal. This is because very specific similarities are unlikely to have arisen convergently and so point towards a single common ancestor for all animals. Recent discoveries of numerous very specific properties shared by all animals provide extremely strong evidence for their common ancestry.

We now know that all animals share not only general similarities but also many highly specific genes, for example, the transcription factors of the *ets* gene family, *paired-box* genes, and a primordial *Hox* gene (Peterson and Davidson 2000). These genes are fundamental in organizing the layout of animal bodies, and have such similar molecular structures that we can confidently conclude that they result from common

ancestry, rather than from later evolutionary convergence. Thus they provide extremely strong evidence that all animal groups arose from only one lineage of single-celled ancestors.

The simplest animals, sponges, have all the characters mentioned above (along with a few unique characters of their own), but they lack the *next* set of features that diagnose an evolutionary clade of animals derived somewhat later. In accordance with the nested hierarchy of characters, we expect all animals, except the sponges, to exhibit embryonic gastrulation (a special infolding of the wall of the initial ball of cells formed after fertilization) and the duplication of the primordial *Hox* gene. These features form the basis for diagnosing a more derived group of animals that includes corals and all other metazoans (ourselves included), but excludes the more basal clade that contains the sponges. At each step of the evolution of animals, we can demonstrate a similar diagnostic branching.

What we have just done is to use the distribution of novel features to map the evolutionary changes that both diagnose what makes an animal in the first place and tell us how animals within the group are related. The resultant hierarchical nested sets of related animals are exactly what we would expect according to an evolutionary model. By any reasonable evaluation, these must be considered strong evidence of the evolutionary relatedness of all animals.

Of course, the spate of new information on molecular structures and developmental genetics raises many new questions, but the big picture is that these new data can only be viewed as furnishing wonderful vindication of Darwin's central notions. Time and time again, we find that animal subgroups thought to be related on the basis of morphological evidence also share exclusive similarities in gene sequences and in patterns of developmental control, as predicted by evolutionary theory. At the Chengjiang meeting, the CRSC's Jonathan Wells suggested that developmental genetic evi-

THE CAMBRIAN DISTORTION

The observers at the Chengjiang conference included Fred Heeren, "the world's only cosmic reporter" <http://www.daystarcom.org/info/author.htm>. Heeren works for the Day Star Network (exploring "the ultimate questions raised by science"), which is organized by Day Star Productions (seeking "to encourage people to seek a close relationship with the Creator/Sustainer of the universe" <http://www.daystarcom.org/info/daystar.com>). Similar statements on the Day Star web site and in Heeren's other publications show that he is promoting apologetics in the guise of science journalism. Heeren supports a form of old-earth creationism and is sympathetic to "intelligent design" (see RT Pennock, *Tower of Babel: The Evidence against the New Creationism*, Cambridge [MA]:The MIT Press, 1999, p 15, 231).

Thus it is not surprising that his "report" on the conference ("A little fish challenges a giant of science", Boston *Globe*, May 30, 2000, E1, E4) claims that the Chengjiang fossils — in particular, *Haikouella*, the "little fish" of the article's title — provide "nothing less than a challenge to the theory of evolution". He cites Chinese paleontologist Jun-Yuan Chen: "the conventional forces of evolution can't account for the speed, the breadth, and one-time nature of 'the Cambrian Explosion'."

Heeren also quoted Eric Davidson (California Institute of Technology) as saying "Neo-Darwinism is dead", and claimed that David J Bottjer (University of Southern California) *conceded* that "[t]he Cambrian Explosion is going to tell us something different about evolution, in the sense that it's not the same story that we have always been taught."

Bottjer and Davidson protested to the *Globe*:

> We deplore the publication by the Boston *Globe* of the recent article "A little fish challenges a giant of science" on 5/30/00, in which we are both (erroneously) quoted. It is strewn with fabrication and fabricated comments and is written by a biblical creationist posing as a science writer who has nothing more than an axe to grind. The least you could do is inform your readers that your editorial policy with regard to "science reporting" is publication of creationist propaganda.

But the *Globe* did not print their letter. Meanwhile, despite the manifest inaccuracy of Heeren's article, it quickly became grist for the creationist mill. For example, Heeren's article is cited (on page 270) in the *research notes* [*sic*] of Jonathan Wells's *Icons of Evolution* (Washington DC: Regnery Press, 2000) and was summarized in one of Chuck Colson's BreakPoint commentaries, which concluded with the thought that natural selection

> can't look into the future and see where to go. Only our Intelligent Designer knows where he's going. And that's why the experts in China and elsewhere have been stumped. Well, we can pray that one day Darwin's legions will see the truth and honor the Creator who designed it all. And in the meantime, you can use this information to set your neighbors and your kids' biology teachers straight <http://www.christianity.com/CC/article/1,1183,PTID2228|CHID|CIID225045,00.html>.

The possessive pronoun and the capitalization are noteworthy. Evidently Colson is unaware that "intelligent design nowhere attempts to identify the intelligent cause responsible for the design of nature" (WA Dembski, *Intelligent Design*, Downers Grove [IL]: InterVarsity Press, 1999, p 247).

[Thanks to Barbara Forrest, and to David Bottjer and Eric Davidson for permission to reprint their letter.]

dence favors separate origins from different single-celled lineages for the major animal groups. But his suggestion contradicts a wealth of scientific evidence and therefore must, in my view, arise from non-scientific convictions.

Our understanding of the major relationships among animal groups is now stabilizing. This is not to say that we currently know all there is to know about animals' relationships or molecular biology — far from it, which is why evolutionary biology is an exciting area of research. Anyone with knowledge of developmental biology and sufficient time can find aspects of specific systems or pathways the operation and evolution of which are not now fully understood. But what we do understand strengthens the case for evolution because new insights and methods of analysis, unthinkable in Darwin's day, yet again fulfill the predictions of the evolutionary model.

What are the implications of the pattern of relatedness discussed above for evolution and for intelligent design creationism? First and most important, it clearly falsifies the IDC claim that animal groups appeared separately and independently. Instead, we see a hierarchy of the distribution of *shared* features — some general to the group as a whole, others specific to particular subgroups. Such a distribution of features is predicted by evolutionary theory, which was proposed long before most of these features had been recognized. It is not concordant with the idea of multiple independent origins of animals, because that model would have no compelling basis on which to predict a hierarchical arrangement of such shared features.

An apologist for "intelligent design" could argue that a designer worked sequentially in a series of small steps, which could explain why the features defining clades are arranged hierarchically. Curiously, however, members of the CRSC apparently do not apply this explanation to the Cambrian biota. Rather, they persist in asserting the independent origins of different animal groups, despite overwhelming scientific evidence against that viewpoint.

The Extensive Precambrian Fossil Record

The second pillar of the IDC position — that major groups of animals appeared too quickly for natural processes to account for them without invoking the intervention of an intelligent designer — is equally unsupported by the scientific evidence. However, to expose the weakness requires some background information about the Precambrian-Cambrian transition.

The earliest fossils currently known occur in rocks from western Australia that date from around 3465 million years ago (Shopf 1993), and a reasonably good fossil record is known from that time onwards. The earliest chemical evidence of life itself is even older, about 3900 million years ago (Mojzsis and Harrison 2000). The earliest fossils are prokaryotic cyanobacteria, and as we move up through the geological column toward the base of the Cambrian these forms are joined by more complex fossils, such as those of eukaryotic cells, by about 1800 million years ago (Knoll 1992). (It is important to reiterate that the first occurrence of a fossil marks the minimum age for the appearance of the group to which it belongs, but the origin of the group often is far earlier, as Darwin suggested. For example, there is good chemical evidence that eukaryotes existed from about 2700 million years ago [Brocks and others 1999], but the earliest fossils yet found that are widely accepted as eukaryotes are some 900 million years younger.)

The increase in complexity and diversity of fossils through the Precambrian up toward the boundary with the Cambrian is concordant with an evolutionary explanation, and the sequence of appearance makes sense in evolutionary terms. Darwin would be justified in feeling vindicated by these discoveries of definitive Precambrian fossils, which were unknown at the time he was writing. Anyone who suggests that Darwin's 19th-century difficulty with an apparently abrupt start to the fossil record still persists today simply has not considered the evidence.

When and how quickly did animals first appear, and did all "major groups" appear at the same time?

We do not yet know exactly when the first animals originated because we do not yet know exactly when the definitive characters of animals — extracellular matrix, the primordial *Hox* gene, the *ets* gene family, and so on — originated. There is a wide range of estimated dates for the differentiation of the major groups of animals from one another. Some studies suggest that this occurred as much as 1100 million years ago; others suggest a date closer to 600 million years ago (see Valentine and others 1999).

Although the methods used in these estimates are not currently as precise as they may yet become, it is hardly a surprise that the dates for the divergence of major groups are spread over a wide timespan. This is because major groups of animals are related in a hierarchical fashion, as we saw above, and would thus be expected to diverge from an ancestral lineage at *different* times. Therefore, we would expect the split between vertebrates and echinoderms, groups that share a wide range of derived features, to have occurred more recently than, say, the split between sponges and the common ancestors of echinoderms and vertebrates. Why? Because sponges are among the most basic animals with the fewest derived features, and so we would expect them to have split off earlier. And this is exactly what we do find — sponges and other animals are estimated to have separated about 950 million years ago, whereas echinoderms and vertebrates split from each other somewhere between 700 and 550 million years ago (Smith 1999).

Three lines of evidence provide important constraints on estimates of when the key events in animal evolution happened. Although the three lines of evidence are independent of one another, the results of each approach are concordant with the inescapable conclusions that the origin of animal groups was a protracted affair that required at least 100 million years and possibly far longer, and that the origin of animal groups took place in the Precambrian, long before the "Cambrian Explosion". Thus the IDC position that the origin of animals occurred very quickly as part of the Cambrian Explosion is falsified by these lines of evidence.

The three lines of evidence are:

Molecular clocks. If we can estimate the rate at which particular organic molecules change among living groups whose divergence times are well known, then we can compare the amount of difference in the same molecules among a wide variety of animals to calculate approximately when these forms diverged. The estimated rate of change in these molecules is the basis for molecular clocks, and the relationships suggested by multiple molecular clocks demonstrate concordant patterns. We now know that the major novel characters that distinguish the major groups of animals appeared at most 1500 million years ago, but at the latest no more than about 560 million years ago — 15 million years before the start of the Cambrian Period (Lynch 1999; Smith 1999), and about 40 million years before the age of the fossils of Chengjiang.

Evidence from body fossils. There is a substantial Precambrian fossil record of animal bodies and body parts. For example the calcareous tube *Cloudina* represents the outer skeleton of an animal, and has long been known from Precambrian rocks at least 550 million years old. There is undisputed evidence of fossil sponges dated about 545 million years ago (Brasier and others 1997), right about at the Cambrian boundary (544 million years ago), but there are also fossils of sponge embryos dated at around 580 million years ago (Chen and others 2000). Some scientists have also argued that some members of the Ediacaran fauna — an enigmatic suite of late Precambrian body fossils about 555 million years old — represent a variety of animal groups with representatives living today. There is widespread agreement that at least some of these forms represent sponges or cnidarians (jellyfishes, corals, sea anemones, and hydras), but some scientists argue that arthropods and mollusks are also present in the Ediacaran assemblages. Moreover, Chen and others (2000) recently claimed to have recovered embryos similar to those of derived groups such as arthropods and echinoderms in deposits about 580 million years old. These researchers argue that early animal evolution took place at small, almost microscopic sizes, and so was unlikely to leave much of a fossil record. If these interpretations of the Precambrian fossil record are correct, they strengthen the case for argument that the differentiation of the "major groups" occurred much earlier than their dramatic appearance in the Cambrian Period.

Evidence from trace fossils. Trace fossils are evidence of the activity of animals, such as the burrows, tracks, and trails that animals left on the sediment surface or beneath it in the seafloor. There is no serious argument that large trace fossils were formed by anything other than animals, although there is some debate as to which are the earliest trace fossils, because many simple trace fossils, such as might be formed by the earliest animals, are easily confused with other structures produced by inorganic processes. One thing is very clear: there are many trace fossils in Precambrian rocks at least 555 million years ago, and possibly far earlier (Budd and Jensen 2000). It is also clear that the order of appearance of trace fossils proceeds sequentially from simple to more complex forms (Budd and Jensen 2000). Indeed, one feature that identifies the Cambrian period in the geological is the appearance of the burrow network *Treptichnus pedum.* The distinctive form of this trace leaves no doubt that it was formed by an animal with a central gut and a reasonably sophisticated neural system. *T pedum* first appears some 10 million years before skeletonized fossils become common and about 20 million years before the Chengjiang fauna lived (about 525 million years ago).

What does all this mean? The lineages that include the major groups of animals (each major group being characterized by a particular "body plan") certainly diverged during the late Precambrian and not during the Cambrian itself. Because major animal groups share so many developmental features, these features must have originated before these lineages split — that is, at least 580 million years ago, some 45 million years before the beginning of the Cambrian Period. Fossil evidence, both from trace and body fossils, is consistent with this interpretation, and the trace fossil record suggests the stepwise acquisition of increasingly complex behaviors from about 555 million years ago onward. Hence, any suggestion that the appearance of the first

representatives of "modern" animal groups in the Cambrian correlates specifically with the time of origin of these groups (an argument favored by proponents of IDC) is clearly refuted by the evidence, which shows that the major groups of animals originated during the Precambrian.

It is also important to appreciate that about 20 million years passed from the beginning of the Cambrian to the time of the Chengjiang fauna — the Burgess Shale fauna (discussed in Gould's *Wonderful Life* [1989]) is even more recent. Because *Treptichnus pedum*, the marker for the start of the Cambrian, was made by an animal with a gut and complex behavior, it is certain that large animals with three layers of cells (the triploblasts) were living long before the debut of the stars of *Wonderful Life*. Any suggestion that animals evolved within "a mere 2 or 3 million years" (Heeren 2000) of the Chengjiang fauna is an irresponsible and bizarre misrepresentation that flatly contradicts scientific facts.

What, then, does the Cambrian Explosion represent?

The Chengjiang fauna, like that of the Burgess Shale and several other Cambrian sites, is truly remarkable for the quality and the range of biological diversity that it preserves. Detailed work on these faunas has revealed a remarkable fact — that animals related to the major living groups of animals were present from at least the later portion of the Early Cambrian Epoch. In *Wonderful Life*, Gould (1989) made much of this important fact by suggesting that because forms comparable to major groups of living animals were already present in the Cambrian, later evolutionary history has mostly involved variation on established themes, rather than the origin of really major new animal body plans. He also stressed that several fundamentally distinct animal body plans present in the Cambrian have since vanished. These body plans are found both in lineages that belong to existing phyla (for example, some extinct groups of Arthropoda) and in lineages that seem allied to other metazoans but are obviously not members of living groups (for example, the Archaeocyatha). Thus, according to Gould, most of the fundamental innovations in body plan were in place by Middle Cambrian time, and the Cambrian fauna was more diverse than its modern counterpart.

New discoveries and interpretations in paleontology and developmental genetics have changed the scientific landscape significantly since Gould wrote *Wonderful Life*. Wills and others (1994) have suggested that Gould may have overestimated the diversity of Cambrian animals, although scientists disagree on how best to measure this diversity. Nevertheless, Gould's central point — that at least some groups of Cambrian animals exhibit a morphological diversity that is at least comparable to that seen in living fauna — remains valid and should not be underestimated. Compared with the fauna of the later Precambrian, the Cambrian fauna is strikingly diverse; the recent discoveries of early vertebrate-like fossils in the Chengjiang beds simply emphasize the point that much innovation was in place by relatively early in the Cambrian Period.

The aspect of Gould's views that has been most strongly challenged is the idea that several fundamentally distinct animal body plans have vanished since the Middle Cambrian. The definition of what constitutes a "fundamentally distinct animal body plan" is difficult because it requires an evaluation of the evolutionary "weight" or significance of particular features; we are not yet sure how to assess this weight objectively. But what has become clear recently is that the Burgess Shale and Chengjiang faunas contain not only members of "crown" groups (those with living representatives), but also animals in "stem" groups, which are more distant relatives of these surviving groups (Budd and Jensen 2000).

Because species belonging to stem groups are typically extinct, their place in the phylogenetic tree can be difficult to interpret. It turns out that many of the forms Gould interpreted as representing additional fundamentally distinct body plans may merely be evolutionary adventures or "experiments" within the lineages of the major groups of animals we know today. So, the unusual fauna of Chengjiang and in the Burgess Shale probably represent way stations along the road to the establishment of the modern groups rather than cul-de-sacs of evolutionary innovation. Some forms we can easily recognize as linked to living groups; others are more enigmatic (and stem groups, of course, show evidence of transitional states). But such difficulty in interpreting early fossils, of course, is what Darwin predicted in the *Origin of Species*, because he knew that the selective action of extinction throughout geological time could only tend to emphasize differences, not similarities, among these major lineages of animals.

The bottom line is that the establishment of modern animal groups was a protracted affair that began no later than about 600 million years ago, extended across the Precambrian–Cambrian boundary, was still in progress during the Early Cambrian Epoch, and continued after the close of the Cambrian Period. Accordingly, science currently tells us that there was, at a minimum, about 100 million years from the time when the first sponge-like animals originated until the origin of representatives of all the major living lineages or body plans.

Because animals did not evolve in a geological instant, there is no need to invoke some novel evolutionary — or supernatural — process to explain their appearance. This is not to say that the appearance of every novel feature is of the same importance for later evolution or that the rate of appearance of novel features was constant throughout the entire interval. Scientists do not demand such restrictions, even though

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How Old is the Earth? Why Should We Care?

Martin G Miller

The earth is old. It is much older than the "creation scientists" would have us believe. And it does not take an advanced degree to see that it is old. All it takes is an open mind, a few observations, and some common sense.

Think of the Grand Canyon. Millions of people visit the Grand Canyon every year and gaze a mile into the earth. They look past more than 3000 feet of colorful, horizontally layered rock, and into the dark, steep Inner Gorge where the Colorado River flows. The layered rock is called "sedimentary" rock. It consists of sediment: particles of pre-existing rock such as sand or silt, or mineral precipitates from marine organisms, that, through time, become cemented into rock. Sandstone, shale, and limestone are sedimentary rocks found in the Grand Canyon. Because sedimentary rock accumulates in layers, the oldest rock lies on the bottom and the youngest lies on top.

By looking at places today where these same rock types form, we can estimate how long it takes for them to accumulate. Using the fastest reasonable rates, the 3500 feet of layered rock in the Grand Canyon would take millions of years to form.

But that is not all. Go in any direction and you will see more. Traveling westward, the same rock units of the Grand Canyon become thicker, reaching about 30 000 feet. We can measure that thickness because those rocks are tilted. By walking along the ground, we can walk across and measure the layers. If you travel northwards to Zion National Park, you will see layers of rock younger than in the Grand Canyon. In Zion, there are 4000 feet of these younger rocks. Beyond Zion, at Bryce Canyon, you encounter still younger rock.

"Creation scientists" like to say all this material was deposited by Noah's flood, rapidly. But what types of material would you expect to see left by such a flood? Boulders and gravel — not the fine-grained sand, shale, or limestone in the Grand Canyon, Zion, and Bryce.

Instead of traveling north or west, try hiking down to the bottom of the Grand Canyon. At the top of the Inner Gorge, the horizontal layers of sedimentary rock rest on top of tilted and faulted layers of other sedimentary rock. These sediments were deposited, cemented into rock, faulted, tilted, and then eroded flat before the horizontal layers above could accumulate.

And below the tilted and faulted layers? An entirely different type of rock: metamorphic rock. Look at a metamorphic rock and you will see that it consists of small crystals which have grown together to make a crude, irregular banding. These types of rocks can only form under conditions of high temperatures and pressures. These rocks formed perhaps 10 miles beneath the earth's surface. Somehow, that metamorphic rock moved from great depths up to the earth's surface where we see it today. And because sedimentary rock was deposited on top of it, it must have come up before the sedimentary rock formed. How long did that take? Our fastest long-term uplift rates are on the order of 2 miles per million years. So at minimum, uplift of the metamorphic rock took 5 million years.

This description is, of course, a simplification. Every added detail requires more time, increasing the age of the earth. What about the multiple periods of erosion through the earth's history that removed, rather than deposited, material? What about the several periods of mountain building that are recorded by buried fault zones and coarse-grained erosional debris? The whole picture, which does get very complicated, is one of an earth whose surface changes over an immense amount of time. To deny that is to miss out on much of the beauty and mystery of our planet.

Why is the age of the earth important? From a practical standpoint, an appreciation of the earth's age is the first step in understanding nonrenewable resources and environmental degradation. Resources form on a geologic time scale while we consume them on a human time scale. Similarly, the earth can heal its scars, but at a rate far slower than we create them.

Symbolically, the great age of the earth drives home humanity's relative youthfulness. For most scientists, many of whom are practicing Christians, this idea adds to the mystery and wonder of our existence. It enhances, rather than conflicts, with their spirituality. In fact, up until the 1960s, nearly all Christians accepted an ancient age for the earth and integrated it with their world view. Even today, mainstream Catholics and Protestants accept an ancient age for the earth.

Today, the age of the earth is under attack by the creation "scientists", the same people who helped remove evolution and cosmology from the required science curriculum in Kansas. They argued that we cannot "see" evolution or cosmology. Similarly, we cannot "see" geologic time. However, we can see the evidence for geologic time — just as with evolution and cosmology. And to appreciate its meaning? All it takes is an open mind and some common sense.

[*Originally published as "Creationists ignore geologic evidence" in the Eugene (Oregon)* Register-Guard, *November 8, 1999; reprinted by permission of Dr Miller.*]

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Thinking about Evolution and Ethics

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

In the ICR's familiar tree of evil, the trunk is evolution and the branches are its supposed immoral consequences — real or imagined — including racism, euthanasia, communism, humanism, perversion, feminism, and so on. The new breed of intelligent design creationists is not much more subtle. Consider the inimitable Nancy Pearcey, Senior Fellow of the Discovery Institute's Center for the Renewal of Science and Culture and Managing Editor of the IDC journal *Origins & Design*, who explains that "Ever since Darwin's day, people have been concerned that his theory undercuts morality in the traditional sense — and they are right" (see <www.arn.org/docs/pearcey/np_dcpolicy0500.htm>). As evidence, she cites a recent song by the Bloodhound Gang with the refrain, "You and me, baby, ain't nothin' but mammals, so let's do it like they do on the Discovery Channel." *Quod erat demonstrandum*. Fortunately, there are people who manage to think clearly, carefully, and cogently about the relationship between evolutionary biology and ethics, even if they do not always reach the same conclusions. Check out the following thoughtful books, now available through the NCSE web site: <www.ncseweb.org/bookcat>. And remember, every purchase benefits NCSE!

Darwinian Natural Right: The Biological Ethics of Human Nature
by Larry Arnhart
In *Darwinian Natural Right*, Larry Arnhart maintains that evolutionary biology favors the Aristotelian view of ethics as rooted in human nature, defining Darwinian natural right in terms of the fulfillment of natural desires based in human biology that are universal to all human societies. "This is one of the best works of its kind that I have read in many years", writes Michael Ruse in *Biology and Philosophy*: "It is extremely well-written and reads beautifully." The author is Professor of Political Science at Northern Illinois University.

Biology and the Foundations of Ethics
edited by Jane Maienschein and Michael Ruse
Collected in *Biology and the Foundations of Ethics* are 12 accomplished essays by distinguished historians and philosophers of science that consider the historical debates over the connection between biology — in particular evolutionary biology — and foundational questions in ethics, from Aristotle through Hume, Darwin, and Nietzsche to EO Wilson. Contributors include Michael Bradie writing on the moral status of animals in 18th-century British philosophy, Paul Farber writing on French evolutionary ethics during the Third Republic, and Michael Ruse writing on the 20th-century biologists George Gaylord Simpson and Julian Huxley.

The Secret Chain: Evolution and Ethics
by Michael Bradie
Part historical treatise, part philosophical analysis, *The Secret Chain* carefully presents and critically evaluates virtually every important discussion of the connection between evolutionary biology and ethics from the 18th century to the present day. Writing in *Creation/Evolution* (1996 Winter; 39: 52-3), Arthur Shapiro remarked that Bradie "has important and novel insights about many of the thinkers he discusses (I was particularly entranced with his comments on Spencer and Kropotkin), but his summation and synthesis come out neither radical nor optimistic for an evolutionary ethics." The author is Professor of Philosophy at Bowling Green State University.

Good-Natured: The Origins of Right and Wrong in Humans and Other Animals
by Frans de Waal
In *Good-Natured*, the primatologist Frans de Waal takes morality as his topic, arguing that we are not the only animals that are capable of distinctively moral behavior. But *Good-Natured* is no dry philosophy text; it teems with striking and touching anecdotes (drawn from de Waal's own observations) of sympathy, reciprocity, and peacemaking among the primates, to say nothing of his excursions into fields as diverse as cognitive ethology, neurobiology, visual anthropology, evolutionary biology, and comparative psychology. By the author of *Peacemaking among Primates* and *Chimpanzee Politics*.

Evolutionary Origins of Morality: Cross-Disciplinary Perspectives
edited by Leonard D Katz
Four lengthy essays — by primatologists Jessica Flack and Frans de Waal, cultural anthropologist Christopher Boehm, philosopher Elliott Sober and evolutionary biologist David Sloan Wilson, and philosopher Brian Skyrms — plus no fewer than 43 short commen-

taries, all revolving around the evolutionary origins of morality. Noam Chomsky comments, "Thoughtful and informative, [the essays] provide a good basis for appreciating what has been achieved, and what the prospects might be, in a domain of inquiry that is of fundamental importance for understanding our essential nature."

The Temptation of Evolutionary Ethics
by Paul Lawrence Farber
In *The Temptation of Evolutionary Ethics*, Farber details the history of three flurries of excitement about evolutionary ethics. The first appeared in the aftermath of the publication of the *Origin of Species*, the second emerged from the cultural chaos following World War I, and the third arrived with the development of sociobiology in the late 20th century. Pessimistic about the prospects for evolutionary ethics, Farber contends that its practitioners are likely to repeat the same philosophical mistakes time after time. The author is Distinguished Professor of the History of Science at Oregon State University.

Issues in Evolutionary Ethics
edited by Paul Thompson
From the publisher, SUNY Press: "This book explores historical and current discussions of the relevance of evolutionary theory to ethics. The historical section conveys the intellectual struggle that took place within the framework of Darwinism from its inception up to the work of GC Williams, WD Hamilton, RD Alexander, RL Trivers, EO Wilson, R Dawkins, and others. The contemporary section discusses ethics within the framework of evolutionary theory as enriched by the works of biologists such as those mentioned above."

Created from Animals: The Moral Implications of Darwinism
by James Rachels
In *Created from Animals*, philosopher James Rachels poses the provocative question "What sort of moral view is consistent with a Darwinian understanding of nature and man's place in it?" His thoughtful answer takes the reader through chapters on evolution, ethics and morals, religion, and human–nonhuman relations. "Evolutionary biologists will likely be fascinated with his explanation", wrote Eugenie C Scott in her review for the *Journal of Human Evolution*.

The Origins of Virtue: Human Instincts and the Evolution of Cooperation
by Matt Ridley
"Our minds have been built by selfish genes, but they have been built to be social, trustworthy and cooperative." A paradox? Not according to Matt Ridley, the author of *The Red Queen: Sex and the Evolution of Human Nature*. His richly multidisciplinary discussion of the science behind human morality scintillates with anecdote and wit. Richard Dawkins exclaims, "If my *Selfish Gene* were to have a volume 2 devoted to humans, *The Origins of Virtue* is pretty much what I think it ought to look like."

Genes, Genesis and God: Values and their Origins in Natural and Human History
by Holmes Rolston III
According to Michael Ruse, writing in *RNCSE* (1999 Sep/Oct; 19 [5]: 38–42), *Genes, Genesis and God* is "a full and fair natural theological attempt to understand modern biology and its relevance for social, ethical, and religious thought. Although I shall have things critical to say about this book ... the author came through as a learned and humane man who has taken seriously his project, and who exhibits intelligence and sensitivity in everything that he writes." Based on the author's 1997 Gifford Lectures.

Taking Darwin Seriously
by Michael Ruse
Here is Michael Ruse's attempt to "work out a full and satisfying position on the basic questions of epistemology (theory of knowledge) and ethics (theory of morality)" by (as the title suggests) taking Darwin seriously. Chapter 3 is devoted to reviewing his precursors in evolutionary ethics, including Herbert Spencer, William Graham Sumner, and EO Wilson, and chapter 6 is devoted to development of his own approach to both substantive and foundational ethics. The revised edition includes a new chapter — "Darwin's New Critics on Trial" — in which Ruse scrutinizes the antievolutionary claims of Phillip Johnson, Michael Behe, and Alvin Plantinga.

Unto Others: The Evolution and Psychology of Unselfish Behavior
by David Sloan Wilson and Elliott Sober
In *Unto Others*, philosopher Elliott Sober and biologist David Sloan Wilson team up to try to reconcile altruism with those scientific discoveries that seem to depict nature as "red in tooth and claw". In the first half, they deal with the prima facie evolutionary objection to altruism by arguing for the feasibility of group selection. In the second half, they carefully examine psychological evidence and philosophical arguments concerning altruism, ultimately concluding that although neither psychology nor philosophy is likely to decide whether altruism exists, there are evolutionary considerations that favor the emergence of unselfishness.

The Moral Animal: Why We Are the Way We Are: The New Science of Evolutionary Psychology
by Robert Wright
The popular science journalist — author of *Three Scientists and Their Gods: Looking for Meaning in an Age of Information* and the recent *Nonzero: The Logic of Human Destiny* — turns his attention to the new science of evolutionary psychology. Summarizing and synthesizing a wealth of state-of-the-art scientific information, Wright provocatively argues that human moral behavior was — and is — largely shaped by our adaptation to the ancestral environment. His points are cheekily exemplified with episodes from the life of Charles Darwin himself. The reviewer for *The Economist* writes, "This clever and stimulating book is destined to become a classic."

NCSE on the Road

A Calendar of Special Events, Presentations, and Lectures

Date	July 26, 2001
City	Pasadena CA
Presenter	Eugenie C Scott (along with Jane Goodall, Kenneth R Miller, and James Moore)
Title	Panel discussion of WGBH's *Evolution* series, which will be broadcast in September 2001
Event	TCA Press Tour
Time	9:00 AM
Location	Ritz-Carleton Hotel
Contact	Eugenie C Scott, scott@ncseweb.org

Date	August 5, 2001
City	Santa Clara CA
Presenter	Eugenie C Scott
Title	When Science Teaching Becomes Controversial
Event	Science Education for New Civic Engagement and Responsibility Program
Time	2:00 PM
Location	Santa Clara University
Contact	Peter Facione, pfacione@scu.edu

Date	October 18, 2001
City	Santa Rosa CA
Presenter	Eugenie C Scott
Title	Mere Evolution
Event	The Once and Future Faith Conference
Time	7:30 PM
Location	Flamingo Hotel
Contact	Charlene Matejovsky, char@westarinstitute.org

Date	October 26, 2001
City	Palm Springs CA
Presenter	Eugenie C Scott
Title	Examining the Icons of Evolution in Textbooks: Good, Bad, and Ugly
Event	California Science Teachers Association Annual Meeting
Time	3:00 PM
Location	TBA
Contact	Scott Hays, shays@telis.prg

Date	November 9, 2001
City	Montreal PQ
Presenter	Eugenie C Scott
Title	Teaching Evolution
Event	National Association of Biology Teachers Annual Meeting
Time	TBA
Location	TBA
Contact	Julie Benyo, julie_benyo@wgbh.org

Date	November 25, 2001
City	Kensington CA
Presenter	Eugenie C Scott
Title	What We Know and Don't Know About Evolution
Event	Personal Theology Series
Time	9:30 AM
Location	Unitarian Universalist Church of Berkeley
Contact	TBA

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

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anti-evolutionists frequently present them as basic premises of evolutionary explanations.

It is clear that there was a fundamental transition that took place over an extended interval across the Precambrian–Cambrian boundary. That transition reflects a dramatic shift in the structure of the ecosystems of early animals, which must have been at least partly fueled by the appearance of new biological innovations. Although a rich mixture of modern groups and their early relatives may have persisted throughout the Cambrian, there is a clear contrast between these generally familiar forms and the more enigmatic fossils from the Precambrian, such as those from Ediacara in Australia. It is clear that the transition into the Cambrian marks a pivotal time in life history. But although much tinkering went on in the Cambrian and thereafter, the most fundamental steps in the origins of animal groups took place during the Precambrian.

To return to Darwin, how does our current knowledge affect his "difficulty" with the "sudden appearance of groups ... in the lowest known fossiliferous strata"? The answer is clear: Darwin's difficulty has evaporated. We have now identified thousands of fossils that appear earlier in the fossil record than the point at which Darwin thought it suddenly began. Darwin suspected that the impression of sudden appearance was false, and speculated that the false impression was due to the poor preservation of the older rocks in Europe and inadequate attention given to the fossil record. He has now been vindicated. The sequence of appearances that we now know is consistent with evolution, and the additional support for the common descent of animal phyla from new lines of inquiry that even Darwin could not have imagined only reinforces the brilliant predictive power of his insight.

Today scientists might quibble about whether he assumed constant rates of evolution with regard to the origin of animals. But despite this disagreement over rates of change, these fossils show that Darwin was right to suggest that life had been around for far longer before the beginning of the Cambrian than it has been since. As a result, it is appropriate to think of the Cambrian as a period of great phylogenetic diversification — what scientists call an evolutionary "radiation."

The Precambrian/Cambrian radiation and creationism: the original spin

Animals are incredibly complex and wonderful, and understanding their early evolution requires a full consideration of many different lines of evidence. Much is known, new data are appearing at an unprecedented rate, and yet many questions still excite our scientific curiosity. Scientists such as Stephen Jay Gould and Simon Conway Morris are valiantly striving to make these exotic animals and abstruse issues accessible to the public. It is a privilege to be able to witness all this excitement.

It is perhaps inevitable that those motivated by a nonscientific agenda will extract snippets and sound bites from the scientific arguments, package them out of context, and feed them to the general public. Fred Heeren, an anti-evolutionist who attended the Chengjiang meeting did just that (*see sidebar, p 19*). He peddled his distorted version of the Cambrian radiation to the popular media, with obvious success (Heeren 2000).

Even if creationist misrepresentation of science is inevitable, it is nevertheless regrettable. Deep time was discovered 200 years ago and is now old news. Almost immediately, scientists recognized the sequential appearance of organisms in the geologic record, demonstrating the development of life's diversity through time, and this has never been seriously questioned in scientific circles. The world will be a better place when its human residents, in the brief flashes of time that each of us is privileged to experience, celebrate what science tells us about our place in nature.

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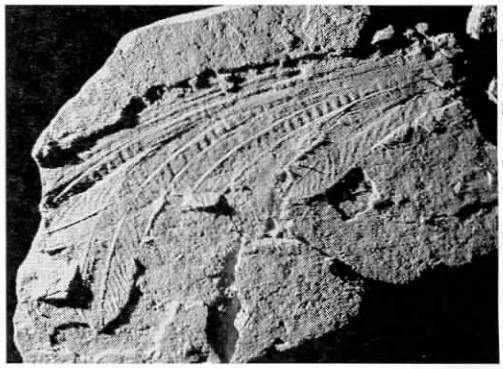

Photograph: Oregon State University

Dinosaurs and Birds – an Update

Kevin Padian
NCSE President

In a short paper in *Nature*, John Ostrom (1973) first laid out a case for the descent of birds from theropod dinosaurs. At the time, other ideas had recently been proposed, linking birds to crocodiles or to a more vaguely defined group of archosaurs (the group that includes birds, dinosaurs, crocodiles, pterosaurs, and many extinct relatives). Although all three hypotheses had early proponents, only the dinosaur-bird hypothesis survived the decade, mainly because (1) the evidence was convincing, (2) the hypothesis survived repeated tests using cladistic analysis, and (3) the alternatives were too vaguely phrased, there was no convincing evidence for them, and they failed repeated cladistic testing. The public tends to think that there is a substantial controversy among scientists about the ancestry of birds, partly because the public does not understand cladistics and partly because cladistics is rejected as a method by the opponents of the dinosaur-bird hypothesis.

What, then, is cladistics? Cladistics, or phylogenetic systematics, is a way of analyzing relationships that was first brought to the fore in the late 1960s, although it had been proposed in Germany decades earlier. By the early 1980s, it had demonstrated its practical and theoretical value to enough of the community of systematists that its methods became commonplace in studies of all branches of organisms, in most top scientific journals, and in the National Science Foundation's decisions about awards in systematic biology. Its influence has grown in succeeding years to the point that statements about evolutionary relationships are no longer taken seriously in the community of systematists unless backed by a cladistic analysis. This is true regardless of the type of organism and regardless of whether the postulated relationship is based on morphology, molecules, behavior, or fossils.

There is no guarantee that any given cladogram will not be revised or overturned by further study (new techniques are constantly being developed and revised); they are hypotheses that are meant to be tested, after all. But cladograms, unlike any other kind of evolutionary hypothesis of relationships, are explicit in their methods and the data on which they are based, and are testable. This gives them practical value. And because they restrict evidence to new, unique evolutionary features as a way of determining relationships among closest relatives, they are more consistent theoretically with the expectations of evolution than any other method.

Cladistics and its Critics

Critics of cladistics (those who still remain), or critics of the dinosaur-bird hypothesis, claim that cladistics has become dogma. To understand how people in the field respond to this complaint, I suggest the following analogy.

Most people accept, on practical as well as theoretical grounds, that medical imaging (X-rays, CAT scans, and so on) shows what is going on inside a patient. Before X-rays, physicians had to operate (dangerous and painful) or feel around on the outside and infer the patient's condition. With modern medical imaging, physicians can easily see an intestinal blockage, a tumor, or a fracture. The people who object to cladistics, decades after its general adoption, are like doctors who would rather feel around to diagnose the problem. It is not that they are necessarily wrong, but now we have better ways to diagnose ailments. If you were sick, would you rather have your doctor just feel around, or use an imaging technique such as an X-ray? At least as a second opinion?

Another criticism, focused on the widespread use of computers in cladistic analysis, is that cladistics is just "garbage in, garbage out". Not so: the computer does not do the thinking for the scientist. The scientist determines which characters and organisms to choose and which states are primitive and derived. The computer's role is just to do electronically what takes much longer to do by hand: namely, sorting out the shortest and simplest evolutionary "family" trees for further testing. It is exactly analogous to using a calculator instead of pencil and paper to add a long list of figures. And every cladistic analysis contains a list of the characters and organisms used and how the character states were coded, so anyone can run the analysis again — with variations, if desired.

Why the emphasis on methods in an article that is supposed to be an update on the dinosaur-bird

hypothesis? Because every couple of months — or so it seems — there is some kind of challenge to the hypothesis, mounted by the same cast of characters. Well, fine; science is built on challenges to what we think we know. But when do we start to decide that a hypothesis is pretty robust to all this testing, and what standards of testing should we require?

Although it has been over 25 years since Ostrom put forth the dinosaur-bird hypothesis, its opponents have yet to propose an alternative, testable hypothesis. So far not a single one of these opponents has ever — and I doubt they ever will — come out and said, "here's another animal or group of animals that we propose as closer to birds than the theropod dinosaurs, and here are the reasons." Their hypothesis is simply that the dinosaur-bird hypothesis is wrong. All the proposed similarities of birds and dinosaurs are mistakes and delusions.

Opponents also claim that the dinosaur-bird hypothesis is dogma, apparently on the grounds that those who accept it have not accepted the opponents' arguments for rejecting it. But science does not require unanimity, it does not force agreement, and it does not settle issues by vote. Some geologists went to their graves not accepting that the continents move. Science progresses nonetheless, by the accumulation of evidence and the testing of hypotheses that account for it. Today it is difficult to find an article in geology that begins by allowing that plate tectonics is only one possible model among many other equally plausible ones — even though 40 years ago the theory was hotly contested.

Well, what methods and tests are the anti-theropod critics using? Not cladistics: they do not use cladistics, because every time someone does a cladistic analysis, birds come out most closely related to theropod dinosaurs. The critics often admit their aversion to cladistics, but even when they do not, their papers speak for them: not a single real cladogram has appeared in any of their works.

Okay, we can all agree that any hegemony of method can be challenged. But in science, we do need methods. What, then, do they propose in place of cladistics? The answer is a resounding silence. They will not say what methods they *are* using, and so it is impossible for anyone to test their statements. Occasionally, they claim that they do not need methods because they have the crucial evidence to falsify the dinosaur-bird hypothesis. Luis Chiappe and I dealt with these objections in several publications, including our 1998 article in *Scientific American* (Padian and Chiappe 1998a) and a longer, more technical one in *Biological Reviews* in the same year (Padian and Chiappe 1998b).

There are two larger points of interest here. I am often asked, by other scientists, by reporters, and by members of the public who are just interested in questions about dinosaurs and evolution, "So what is it with these anti-theropod people? It sounds like you are arguing with creationists." And here, especially for the NCSE audience, I would like to demur on this comparison. It is intellectually dissonant to mention these two groups in the same sentence, because obviously the dissenters to the dinosaur-bird hypothesis are competent scientists who accept evolution.

But the comparison appears to recur because, if you present no alternative hypothesis to test scientifically, and you do not accept the methods of the field yet have no alternative methods that can be used, at some point observers will begin to wonder about the scientific basis for your statements. I think, in fairness to these dissenters, that they hold that evolutionary processes, as they understand them, would not be able to produce birds from dinosaurs; so the evolutionary patterns that we see in cladograms must be wrong.

The second point has to do with public education. Why does the public not understand the methodological basis of this dispute? The answer is two-pronged. First, the reporters assigned to cover the story do not make the

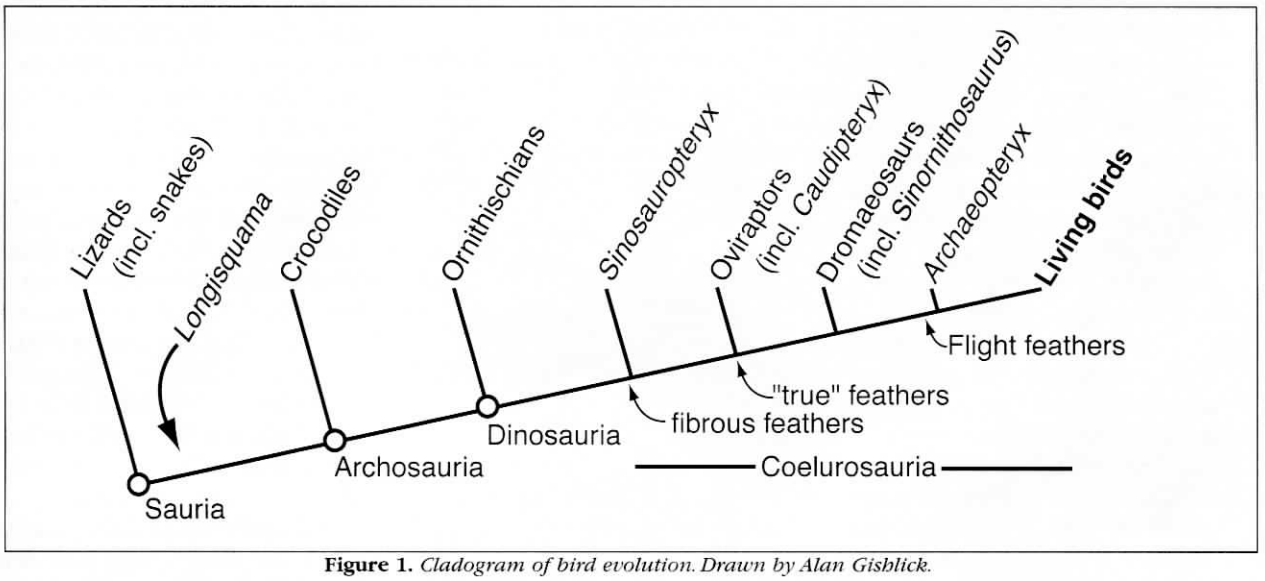

Figure 1. *Cladogram of bird evolution. Drawn by Alan Gisblick.*

issue clear to the public. This is because most of them do not understand it; they think that the dispute is largely motivated by personalities and politics in the absence of definitive evidence. It could be improved if reporters would explain at least a bit about the methods and standards of evidence, as opposed to "he said, she said" journalism. But after all, they are journalists, and we cannot expect them to be scientists too, any more than scientists can be competent reporters.

The second reason, which encompasses the first, is that even though cladistic analysis has been the standard for the field for two decades, it is almost unknown to the general public. Textbooks continue to teach the outworn Linnaean system and to portray taxonomy as some kind of art, instead of as a process that arranges organisms according to scientifically tested hypotheses about the evolutionary changes that produced a variety of descendants from a common ancestor.

Recent Developments in Bird Evolution

Recent developments illustrate some problems faced by the opponents of the dinosaur-bird hypothesis. Most readers will have heard that several kinds of feathered dinosaurs have been recently discovered in the Early Cretaceous deposits of Liaoning Province, China. They belong to several distinct groups within the broader group of coelurosaurian dinosaurs — the group to which all systematic analyses conclude that birds belong.

What sort of feathers do these dinosaurs have? Well, they have two kinds of integumentary structures. One kind produces a thick, relatively short and dense pelage made up of fibrous, filamentous structures that appear all over the body. These, claim some opponents of the dinosaur-bird hypothesis, are merely collagen (a common connective tissue in skin). However, molecular analysis shows that these structures are made of keratin — and not just any keratin, but the *beta*-keratin that feathers have (and, equally important, not the *alpha*-keratin that make up the scales of today's reptiles). Dinosaurs that have this kind of integumentary structure include several coelurosaurian theropods, such as the compsognathid *Sinosauropteryx*, the therizinosaurid *Beipiaosaurus*, and the dromaeosaur *Saurornithosaurus* (listed in order of their closeness to birds). More feathered coelurosaurs are being discovered and described in the scientific literature.

The second kind of integument is true feathers, which have a central shaft, two vanes, and barbs. These true feathers are attached to the forelimbs and tail just as the feathers of *Archaeopteryx* and living birds are. True feathers are found in the oviraptorosaur *Caudipteryx* and another form, *Protarchaeopteryx*, which are coelurosaurs. Opponents of the dinosaur-bird hypothesis have claimed that these are merely birds that have given up the ability to fly, but because they have not performed a phylogenetic analysis of any sort, they have no support for this assertion.

Opponents of the dinosaur-bird hypothesis keep publishing objections that are based on alternative interpretations of single features or specimens, which by themselves do not falsify the dinosaur-bird hypothesis. The most recent is a re-interpretation of *Longisquama*, an enigmatic reptile of undetermined relationship that occurs in the Triassic of Kazakhstan. It has been known for 30 years, but what is most interesting about *Longisquama* are the long oblong structures that appear to emanate from its vertebral column. Each of these structures has a central stalk that separates two flat, semi-elliptical surfaces. There are no barbs, but there are some features emanating from the stalk, wavy in contour, directed proximally near the base of the stalk and distally near its end. The entire structure is surrounded by a perimeter reminiscent of a rubber band. (*See the cover photograph.*)

The re-interpretation of this specimen as possessing true feathers (Jones and others 2000) was supposed to overturn the dinosaur-bird hypothesis, according to an aggressive press release and statements made for the benefit of the media, but for the most part it just left paleontologists scratching their heads. No one appeared to be postulating *Longisquama* as the closest relative of birds, so what were we supposed to learn from this publication? Perhaps we were to be admonished that the fossil record is rich enough to contain plenty of surprises, and so we should not be so confident in the dinosaur-bird hypothesis. Okay, caution taken. Now, what is the alternative hypothesis? And what is the method used to frame it?

Well, there is no hypothesis, and there is no method. Two major problems in the re-interpretation of *Longisquama* indicate the pitfalls of the "alternative" approach. First, the opponents of the dinosaur-bird hypothesis who published this paper asserted that *Longisquama* was an archosaur, but it is not. Archosaurs (by definition) include birds and crocodiles and all descendants of their closest common ancestor. No analysis yet has placed *Longisquama* anywhere near this group. Rather, it is

Read More About Cladistics

Readers who want to learn more about cladistics could examine one of the following:

DR Brooks and DA McLennan. *Phylogeny, Ecology, and Behavior*. Chicago: University of Chicago Press, 1991.

Joel Cracraft and Niles Eldredge. *Phylogenetic Patterns and the Evolutionary Process*. New York: Columbia University Press, 1980.

Henry Gee. *In Search of Deep Time*. New York: The Free Press, 1999.

EO Wiley. *Phylogenetics*. New York: John Wiley & Sons, 1981.

Sermon Under the Mount

Matthew Chapman

In the spring of 1998, I decided to write a book about the 1925 Scopes "Monkey" Trial, the celebrated trial of a schoolteacher accused of teaching evolution in defiance of Tennessee law. This was not an arbitrary choice. My great-great-grandfather was Charles Darwin — something I had given little thought to as an adult until I came to live in America and discovered that his theories were still rabidly contested here. A 1999 US Gallup poll found that 40% of those surveyed favored teaching creationism instead of evolution in public schools. That same year, the Kansas State Board of Education voted to delete virtually every mention of evolution from the state's science curriculum.

In early childhood I was told how Darwin's theory of evolution had demolished the biblical story of creation. And if the very first chapter of the Good Book was nonsensical and untrue, why should the rest be any more credible or useful? My parents made an attempt to raise me as a Christian, but ultimately lacked the conviction to boost me over the numerous improbabilities.

Most modern scientists — perhaps 99% — believe the world is about 4 billion years old. Professor Kurt Wise, associate professor of science and director of origins research at Bryan College in Dayton, Tennessee, puts its age at somewhere around 6000 years. Kurt teaches his course in two parts: the first from the perspective of theistic evolution, that is, the idea that God used evolution over long periods of time to create the universe. The second half of the course presents what he really believes: that the "six days of creation" were in fact regular "earth rotation days" because the same word for "day" is used in the Ten Commandments when we are instructed to work six days and rest on the seventh.

Spelunking With Kurt Wise

Kurt is taking a group of Bryan College summer students on a cave geology tour and he invites me along. Several white vans, replete with Christian youth, are parked outside the college. I find one with an empty seat at the back, clamber past a group of clean-cut types of both sexes, and settle in for the ride. "I hear, like, intellectuals, a lot of them commit suicide?" squeaks one teenage boy, "'Cause they believe what they're taught, evolution an' all, so they got nothing to live for?" And now he fixes me with a mordant look, like maybe I am one of them. "That's true, statistically true", says another young man. "They don't have God in their

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apparently somewhere within Sauria, the broad group that includes living lizards and snakes, *Sphenodon*, crocodiles, birds, and all the descendants of their most recent common ancestor. The specimens preserve too few features to be much more specific. So it is implausible that this animal had anything to do with the origin of birds.

The second error is the assertion that *Longisquama* had true feathers (Reisz and Sues 2000). Reporters found it difficult to get anyone else to agree with this (Stokstad 2000). The two most noted experts on feather structure and development rejected the idea, and one opined that the paper would not have been published in even a third-rate ornithological journal. As noted above, the similarities to feathers are superficial at best. Why, then, did the paper receive such attention in the popular and scientific press? Well, scientific journalism, especially in high-profile journals, is not above a bit of the "Man Bites Dog" mentality; there is competition to report on what seems new and exciting, even in the news sections of peer-reviewed publications.

Let me propose a litmus test. Next time you encounter a newspaper or television story on this or any scientific issue, get to the bottom of it with two questions: (1) What exact hypothesis is being proposed here to supplant another one (and it cannot be simply that the first hypothesis is wrong: we assume that in all tests)? (2) What methods are being used, if not the standard methods in the field, and how do we know that these are better than the standard methods? If and when the opponents of the dinosaur-bird hypothesis manage to give satisfactory answers to these two questions, they will be taken seriously.

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lives, they don't have Jesus as their personal savior." "Amen", says one of the girls.

We have been driving for half an hour before they ask me why I am here. I keep it simple: a book on the Scopes trial. Most of them are from rural states: South and North Carolina, West Virginia, Pennsylvania, Utah, and Minnesota. Many have been taught at home; most are pleasant but uninteresting, the weird similarity of their views making it hard to distinguish one from another. After about an hour, we arrive at Grassy Cove, a pastoral valley between faint blue mountains, and turn off the main road on to a dirt track. There must be at least 50 of us tramping along in the heat. The entrance to the cave is a ragged horizontal slit, like a mouth clumsily hacked into a Halloween pumpkin. Even more alarming, it is at ground level. Hardy Christian students insert themselves into it with difficulty, slither down in steep descent and disappear. Kurt has divided us into small groups, which depart at intervals of five or 10 minutes.

Flashlight-less, intensely dubious, I squeeze through the hole. The downward skid is actually quite short. I find myself muddy but uninjured. As Kurt cannot be at every "point of interest", he has stationed older students at each, all holding a piece of paper on which is typed what Kurt would have said had he been there: "The Flood Did It". That's the basic message. What the majority of geologists believe took millions of years, Kurt and his fellow creationists believe was done a few thousand years ago in a matter of months, when Noah was forced to sea with all the animals on earth, including his family but excluding the fish.

We're asked by the first of Kurt's surrogates, a young woman, to observe a well-preserved fossilized brachiopod (a kind of shellfish) in limestone. We are 1000 feet above current sea level, and you can find fossils like this all across America at similar elevations. If brachiopods decay or if they get moved any distance, the muscle that holds the shells together fails, and the shells separate. Modern brachiopods, if they're found whole at all, we are told, are usually found with the shell open and the opening facing upward. This fossilized brachiopod appears to be complete, has its shell closed, and it is on the tilt. To Kurt, this suggests that "the critter" was still alive when it was deposited, which suggests it was buried rapidly, which suggests, as Kurt puts it, "a global diluvial catastrophe".

The student, reading Kurt's words, goes on to talk about the stalagmites near the entrance. Kurt argues that, as these stalagmites, though large, occupy less than 1% of the available space in the cave, they may not be as old as other geologists think; if they were, they would have filled the place up and we would not be here. The cave is so grotesquely dramatic, so tortured, that Kurt's theory — suggesting an upheaval as violent as one's own alarm — does have emotional resonance. Certainly I can imagine a roiling wall of grey mud and rock roaring and cascading into the cave and carving out this infernal canyon. But Kurt seems to want to have his cave and eat it too: this deluge was so fantastically fierce that it burrowed this vast warren out of solid rock in under a year, yet not so fierce as to pulverize the delicate, twin-shelled brachiopod.

Inside the next room lurks our new guide, a smiling, sanctimonious young man. When we are all gathered inside, he tells us to sit down and switch off our flashlights. Then, out of the blackness, comes his pious young voice: "Why don't you lead off, Brittany?" "My God is an awesome God!" sings Brittany in a sweet, high voice, and then the rest join in. "Be praised!" Then they all sing together: "My God is an awesome God! Be praised!" The room sounds like a small cathedral, more bass, less echo, but it is, I have to admit, pretty awesome, particularly in the darkness.

Then we wander off toward the final and most horrific room of all: a vast, meandering, asymmetrical cavern. The ceiling is only 2-3 feet from the floor and appears to be supported only by occasional rough columns formed by stalactites and stalagmites fusing together, each column tapering in the middle like some weirdly guttered candle. On top of this massive slab there is a billion tons of mountain and some loony creationist is asking you to crawl into this awful, ill-supported geological death-gap, which, if it collapsed, would leave you flatter than a dime, all so he can expound, through delegates, some nutty theory which every reasonable man on earth knows is utter hogwash. Only a fool would enter. In I crawl.

Out of the Depths

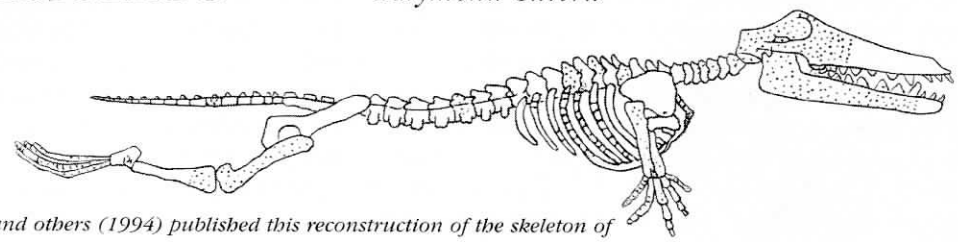
We reach a central column, and slump down to listen to a lecture. I remember none of it. Finally, we are backing out; the mood lightens immediately, suggesting that perhaps I was not alone in my claustrophobic terror. The girls become chatty. I ask what the rules are. Most of them are obvious: no drugs, no cigarettes, no alcohol. A girl fills me in on the dress code. "No tank tops, no tube tops, no halter tops, no spaghetti straps, no short shorts, and you have to have a one-piece bathing suit." As we wind our way up towards daylight, the girls become almost evanescent. One of them asks if I am a believer; I guess they have rumbled [*detected - ed.*] me.

"You should come and sit in on some of our classes," she says. "It would be really helpful." The atmosphere on the drive back toward Bryan College is friendlier than it was on the way here. They know who I am; they have absorbed it and are willing to talk freely about themselves and their beliefs. Their religion, they tell me, is the only true religion, unique because Jesus Christ, the son of God, set foot on earth. No other religion can make that claim.

The girls state that they would not marry a non-believer. In fact, they would not even marry a Catholic unless he was born again because it would be hard to live with someone whom you knew

The Origin of Whales and the Power of Independent Evidence

Raymond Sutera



Thewissen and others (1994) published this reconstruction of the skeleton of Ambulocetans natans *(redrawn for* RNCSE *by Janet Dreyer).*

How do you convince a creationist that a fossil is a transitional fossil? Give up? It is a trick question. You cannot do it. There is no convincing someone who has his mind made up already. But sometimes, it is even worse. Sometimes, when you point out a fossil that falls into the middle of a gap and is a superb morphological and chronological intermediate, you are met with the response: "Well, now you have two gaps where you only had one before! You are losing ground!"

One of the favorite anti-evolutionist challenges to the existence of transitional fossils is the supposed lack of transitional forms in the evolution of the whales. Duane Gish of the Institute for Creation Research (ICR) regularly trots out the "bossie-to-blowhole" transition to ridicule the idea that whales could have evolved from terrestrial, hooved ancestors.

> There simply are no transitional forms in the fossil record between the marine mammals and their supposed land mammal ancestors . . . It is quite entertaining, starting with cows, pigs, or buffaloes, to attempt to visualize what the intermediates may have looked life. Starting with a cow, one could even imagine one line of descent which prematurely became extinct, due to what might be called an "udder failure" (Gish 1985: 78–9).

Of course, for many years the fossil record for the whales was quite spotty, but now there are numer-

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was going to hell. Of all their beliefs, I tell them, this born-again-or-go-to-hell thing is the one I find hardest to take. If God is so perfect, why would he care whether you believed in him or not? It seems so petty. Believing in a literal hell, an inferno of unimaginable suffering, they accept with equanimity that seven-eighths of the world, including me, will end up in it. Forever.

I am glad to arrive back at the college to be offered hotdogs from a barbecue grill. (The flames! The flames!) I take my food over to a patch of grass and sit down next to a couple of fellow cave-survivors. Exhausted and vaguely depressed, I find Kurt, thank him, and leave.

If I went down to Dayton an atheist, I came back an agnostic, refusing to share the arrogance of any conviction in a matter so clearly unprovable either way. In his autobiography, Darwin, who also called himself an agnostic, wrote that the magnificence of the universe almost forces one to conclude that God exists. However, he continued, "Can the mind of man, which has, as I fully believe, been developed from a mind as low as that possessed by the lowest animal, be trusted when it draws such grand conclusions?" He goes on to say that the problem is compounded by "the probability that the constant inculcation in a belief in God on the minds of children has produced so strong and perhaps inherited effect on their brains, that it may now be as difficult for them to throw off their belief in God as for a monkey to throw off its instinctive fear of a snake." For this monkey at least, my great-great-grandfather was right.

This extract is adapted from Trials of the Monkey: An Accidental Memoir, *London: Duck Editions, 2000. Reprinted with permission from* Guardian Unlimited © *Guardian Newspapers Limited 2000.*

ous transitional forms that illustrate the pathway of whale evolution.

Recent discoveries of fossil whales provide the evidence that will convince an honest skeptic. However, evolutionary biology predicts more than just the existence of fossil ancestors with certain characteristics — it also predicts that all other biological disciplines should also reveal patterns of similarity among whales, their ancestors, and other mammals, correlated with evolutionary relatedness between groups. It should be no surprise that this is what we find, and since the findings in one biological discipline, say biochemistry, is derived without reference to the findings in another, say comparative anatomy, scientists consider these different fields to provide independent evidence of the evolution of whales. As expected, these independent lines of evidence all confirm the pattern of whale evolution that we would anticipate in the fossil record.

To illustrate this approach, I will present the evidence from multiple fields for the origin of the whales from terrestrial mammals. This paper will examine mutually reinforcing evidence from nine independent areas of research. Of course, as a starting point, we need to describe what makes a whale a whale.

What is a whale?

A whale is first and foremost, a mammal — a warm-blooded vertebrate that uses its high metabolism to generate heat and regulate its internal temperature. Female whales bear live young, which they nurse from mammary glands. Although adult whales have no covering of body hair, they acquire body hair temporarily as fetuses, and some adult whales have sensory bristles around their mouths. These features are unequivocally mammalian.

But a whale is a very specialized mammal with many unique characters that are not shared with other mammals — many of these are not even shared with other marine mammals such as sirenians (manatees and dugongs) and pinnipeds (seals, sea lions, and walruses). For example, whales have streamlined bodies that are thick and rounded, unlike the generally slim, elongated bodies of fishes. A whale's tail has horizontal flukes, which are its sole means of propulsion through the water. The dorsal fin is stiffened by connective tissue, but is fleshy and entirely without supporting bones.

The neck vertebrae of the whale are shortened and at least some are fused into a single bony mass. The vertebrae behind the neck are numerous and very similar to one another; the bony processes that connect the vertebrae are greatly reduced, allowing the back to be very flexible and to produce powerful thrusts from the tail flukes. The flippers that allow the whale to steer are composed of flattened and shortened arm bones, flat, disk-like wrist bones, and multiple elongated fingers. The elbow joint is virtually immobile, making the flipper rigid. In the shoulder girdle, the shoulder blade is flattened, and there is no clavicle. A few species of whales still possess a vestigial pelvis, and some have greatly reduced and nonfunctional hindlimbs.

The rib cage is very mobile — in some species, the ribs are entirely separated from the vertebral column — which allows the chest to expand greatly when the whale is breathing in and to compress at depth when the whale is diving deeply.

The skull also has a set of features unique among mammals. The jaws extend forward, giving whales their characteristically long head, and the two frontmost bones of the upper jaw (the maxillary and premaxillary) are "telescoped" rearward, sometimes entirely covering the top of the skull. The rearward migration of these bones is the process by which the nasal openings have moved to the top of the skull, creating blowholes and shifting the brain and the auditory apparatus to the back of the skull. The odontocetes (toothed whales) have a single blowhole, while the mysticetes (baleen whales) have paired blowholes.

In the odontocetes, there is a pronounced asymmetry in the telescoped bones and blowhole that provides a natural means of classification. Only odontocetes exhibit teeth as adults, although teeth often occur in fetal mysticetes. These teeth are always simple cones or pegs; they are not differentiated by function or region as teeth are in other mammals. (Whales cannot chew their food; it is ground up instead in a forestomach, or muscular crop, containing stones.)

Unlike the rest of the mammals, whales have no tear glands, no skin glands, and no olfactory sense. Their hearing is acute but the ear has no external opening. Hearing occurs via vibrations transmitted to a heavy, shell-like bone formed by fusion of skull bones (the periotic and auditory bullae).

These, then, are the major features of whales. Some clearly show the distinctive adaptations imposed on whales by their commitment to marine living; others clearly link the whales to their terrestrial ancestors. Others show the traces of descent from a terrestrial ancestor in common with several ancient and modern species. From all these features together, we can reconstruct the pathway that whale evolution took from a terrestrial ancestor to a modern whale confined to deep oceans.

Thinking about the ancestry of the whale

In 1693, John Ray recorded his realization that whales are mammals based on the similarity of whales to terrestrial mammals (Barnes 1984). The pre-Darwinian scientific discussion revolved around whether whales were descended from or ancestral

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to terrestrial mammals. Darwin (1859) suggested that whales arose from bears, sketching a scenario in which selective pressures might cause bears to evolve into whales; embarrassed by criticism, he removed his hypothetical swimming bears from later editions of the *Origin* (Gould 1995).

Later, Flower (1883) recognized that the whales have persistent rudimentary and vestigial features characteristic of terrestrial mammals, thus confirming that the direction of descent was from terrestrial to marine species. On the basis of morphology, Flower also linked whales with the ungulates; he seems to have been the first person to do so.

Early in the 20th century, Eberhard Fraas and Charles Andrews suggested that creodonts (primitive carnivores, now extinct) were the ancestors of whales (Barnes 1984). Later, WD Matthew of the American Museum of Natural History postulated that whales descended from insectivores, but his idea never gained much support (Barnes 1984). Later still, Everhard Johannes Slijper tried to combine the two ideas, claiming that whales descended from what Barnes aptly called "creodonts-*cum*-insectivores". However, no such animal has ever been found. More recently, Van Valen (1966) and Szalay (1969) associated early whales with mesonychid condylarths (a now-extinct group of primitive carnivorous ungulates, none bigger than a wolf) on the basis of dental characters. More recent evidence confirms their assessment. Thus Flower was basically right.

The evidence

The evidence that whales descended from terrestrial mammals is here divided into nine independent parts: paleontological, morphological, molecular biological, vestigial, embryological, geochemical, paleoenvironmental, paleobiogeographical, and chronological. Although my summary of the evidence is not exhaustive, it shows that the current view of whale evolution is supported by scientific research in several distinct disciplines.

1. Paleontological evidence

The paleontological evidence comes from studying the fossil sequence from terrestrial mammals through more and more whale-like forms until the appearance of modern whales. Although the early whales (Archaeocetes) exhibit greater diversity than I have space to discuss here, the examples in this section represent the trends that we see in this taxon. This discussion will focus on the origin of the whales as an order of mammals, and set aside the issues related to the diversification into the two modern suborders of whales (Odontocetes and Mysticetes).

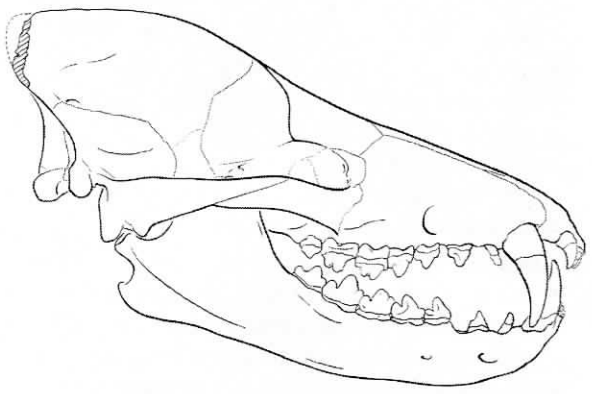
Sinonyx

We start with *Sinonyx*, a wolf-sized mesonychid (a primitive ungulate from the order Condylarthra; this order includes artiodactyls, perissodactyls, proboscideans, and so on) from the late Paleocene, about 60 million years ago. The characters that link *Sinonyx* to the whales, thus indicating that they are relatives, include an elongated muzzle, an enlarged jugular foramen, and a short basicranium (Zhou and others 1995). The tooth count was the primitive mammalian number (44); the teeth were differentiated as are the heterodont teeth of today's mammals. The molars were very narrow shearing teeth, especially in the lower jaw, but possessed multiple cusps. The elongation of the muzzle is often associated with hunting fish — all fish-hunting whales, as well as dolphins, have elongated muzzles. These features were atypical of mesonychids, indicating that *Sinonyx* was already developing the adaptations that later became the basis of the whales' specialized way of life.

Pakicetus

The next fossil in the sequence, *Pakicetus*, is the oldest cetacean, and the first known archaeocete. It is from the early Eocene of Pakistan, about 52 million years ago (Gingerich and others 1983). Although it is known only from fragmentary skull remains, those remains are very diagnostic, and they are definitely intermediate between *Sinonyx* and later whales. This is especially the case for the teeth. The upper and lower molars, which have multiple cusps, are still similar to those of *Sinonyx*, but the premolars have become simple triangular teeth composed of a single cusp serrated on its front and back edges. The teeth of later whales show even more simplification into simple serrated triangles, like those of carnivorous sharks, indicating that *Pakicetus*'s teeth were adapted to hunting fish.

A well-preserved cranium shows that *Pakicetus* was definitely a cetacean with a narrow braincase, a high, narrow sagittal crest, and prominent lambdoidal crests. Gingerich and others (1983) reconstructed a composite skull that was about 35 centimeters long. *Pakicetus* did not hear well underwater. Its skull had neither dense tympanic bullae nor sinuses isolating the left auditory area from the right



Zhou and others (1995) published this recontruction of the skull of Sinonyx jiashanensis *(redrawn for* RNCSE *by Janet Dreyer).*

one — an adaptation of later whales that allows directional hearing under water and prevents transmission of sounds through the skull (Gingerich and others 1983). All living whales have foam-filled sinuses along with dense tympanic bullae that create an impedance contrast so they can separate sounds arriving from different directions. There is also no evidence in *Pakicetus* of vascularization of the middle ear, which is necessary to regulate the pressure within the middle ear during diving (Gingerich and others 1983). Therefore, *Pakicetus* was probably incapable of achieving dives of any significant depth. This paleontological assessment of the ecological niche of *Pakicetus* is entirely consistent with the geochemical and paleoenvironmental evidence. When it came to hearing, *Pakicetus* was more terrestrial than aquatic, but the shape of its skull was definitely cetacean, and its teeth were between the ancestral and modern states.

Ambulocetus

In the same area that *Pakicetus* was found, but in sediments about 120 meters higher, Thewissen and colleagues (1994) discovered *Ambulocetus natans*, "the walking whale that swims", in 1992. Dating from the early to middle Eocene, about 50 million years ago, *Ambulocetus* is a truly amazing fossil. It was clearly a cetacean, but it also had functional legs and a skeleton that still allowed some degree of terrestrial walking. The conclusion that *Ambulocetus* could walk by using the hind limbs is supported by its having a large, stout femur. However, because the femur did not have the large attachment points needed for walking muscles, it could not have been a very efficient walker. Probably it could walk only in the way that modern sea lions can walk — by rotating the hind feet forward and waddling along the ground with the assistance of their forefeet and spinal flexion. When walking, its huge front feet must have pointed laterally to a fair degree since, if they had pointed forward, they would have interfered with each other.

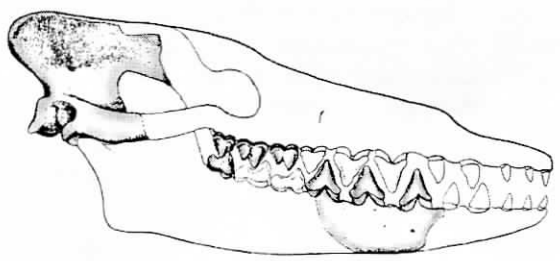
The forelimbs were also intermediate in both structure and function. The ulna and the radius were strong, so the forelimb was capable of carrying the weight of the animal on land. The elbow was strong but it was inclined rearward, making possible rearward thrusts of the forearm for swimming. However, the wrists, unlike those of modern whales, were flexible.

It is obvious from the anatomy of the spinal column that *Ambulocetus* must have swum with its spine swaying up and down, propelled by its back feet, oriented to the rear. As with other aquatic mammals using this method of swimming, the back feet were quite large. Remarkably, the toes of the back feet terminated in *hooves*, thus advertising the ungulate ancestry of the animal. The only tail vertebra found is long, making it likely that the tail was also long. The cervical vertebrae were relatively long, compared to those of modern whales; *Ambulocetus* must have had a flexible neck.

Ambulocetus's skull was quite cetacean (Novacek 1994). It had a long muzzle, teeth that were very similar to later archaeocetes, a reduced zygomatic arch, and a tympanic bulla (which supports the eardrum) that was poorly attached to the skull. Although *Ambulocetus* apparently lacked a blowhole, the other skull features qualify *Ambulocetus* as a cetacean. The post-cranial features are clearly in transitional adaptation to the aquatic environment. Thus *Ambulocetus* is best described as an amphibious, sea-lion-sized fish-eater that was not yet totally disconnected from the terrestrial life of its ancestors.

Rodhocetus

In the middle Eocene (46–7 million years ago) *Rodhocetus* took all of these changes even further, yet still retained a number of primitive terrestrial features (Gingerich and others 1994). It is the earliest archaeocete of which all of the thoracic, lumbar,



Gingerich and others (1983) published this recontruction of the skull of Pakicetus inachus *(redrawn for* RNCSE *by Janet Dreyer).*

and sacral vertebrae have been preserved. The lumbar vertebrae had higher neural spines than in earlier whales. The size of these extensions on the top of the vertebrae where muscles are attached indicate that *Rodhocetus* had developed a powerful tail for swimming.

Elsewhere along the spine, the four large sacral vertebrae were unfused. This gave the spine more flexibility and allowed a more powerful thrust while swimming. It is also likely that *Rodhocetus* had a tail fluke, although such a feature is not preserved in the known fossils: it possessed features — shortened cervical vertebrae, heavy and robust proximal tail vertebrae, and large dorsal spines on the lumbar vertebrae for large tail and other axial muscle attachments — that are associated in modern whales with the development and use of tail flukes. All in all, *Rodhocetus* must have been a very good tail-swimmer, and it is the earliest fossil whale committed to this manner of swimming.

The pelvis of *Rodhocetus* was smaller than that of its predecessors, but it was still connected to the sacral vertebrae, meaning that *Rodhocetus* could still

walk on land to some degree. However, the ilium of the pelvis was short compared to that of the mesonychids, making for a less powerful muscular thrust from the hip during walking, and the femur was about ⅓ shorter than *Ambulocetus*'s, so *Rodhocetus* probably could not get around as well on land as its predecessors (Gingerich and others 1994).

Rodhocetus's skull was rather large compared to the rest of the skeleton. The premaxillae and dentaries had extended forward even more than its predecessors', elongating the skull and making it even more cetacean. The molars have higher crowns than in earlier whales and are greatly simplified. The lower molars are higher than they are wide. There is a reduced differentiation among the teeth. For the first time, the nostrils have moved back along the snout and are located above the canine teeth, showing blowhole evolution. The auditory bullae are large and made of dense bone (characteristics unique to cetaceans), but they apparently did not contain the sinuses typical of later whales, making it questionable whether *Rodhocetus* possessed directional hearing underwater.

Overall, *Rodhocetus* showed improvements over earlier whales by virtue of its deep, slim thorax, longer head, greater vertebral flexibility, and expanded tail-related musculature. The increase in flexibility and strength in the back and tail with the accompanying decrease in the strength and size of the limbs indicated that it was a good tail-swimmer with a reduced ability to walk on land.

Basilosaurus

The particularly well-known fossil whale *Basilosaurus* represents the next evolutionary grade in whale evolution (Gingerich 1994). It lived during the late Eocene and latest part of the middle Eocene (35–45 million years ago). *Basilosaurus* was a long, thin, serpentine animal that was originally thought to have been the remains of a sea serpent (hence its name, which actually means "king lizard"). Its extreme body length (about 15 meters) appears to be due to a feature unique among whales; its 67 vertebrae are so long compared to other whales of the time and to modern whales that it probably represents a specialization that sets it apart from the lineage that gave rise to modern whales.

What makes *Basilosaurus* a particularly interesting whale, however, is the distinctive anatomy of its hind limbs (Gingerich and others 1990). It had a nearly complete pelvic girdle and set of hindlimb bones. The limbs were too small for effective propulsion, less than 60 cm long on this 15-meter–long animal, and the pelvic girdle was completely isolated from the spine so that weight-bearing was impossible. Reconstructions of the animal have placed its legs external to the body — a configuration that would represent an important intermediate form in whale evolution.

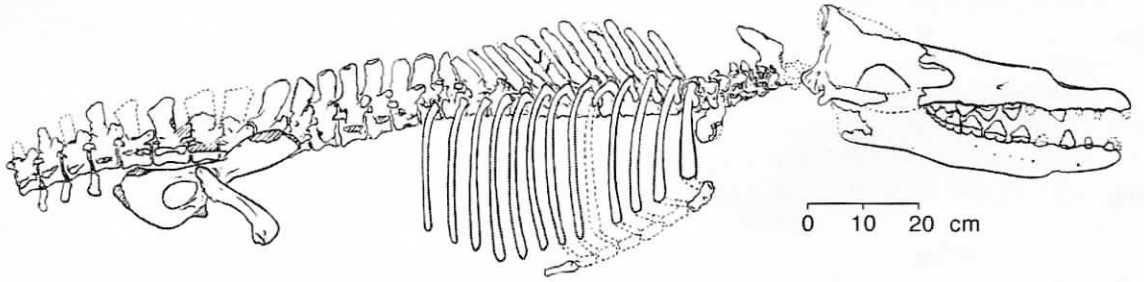
Although no tail fluke has ever been found (since tail flukes contain no bones and are unlikely to fossilize), Gingerich and others (1990) noted that *Basilosaurus*'s vertebral column shares characteristics with those of whales that do have tail flukes. The tail and cervical vertebrae are shorter than those of the thoracic and lumbar regions, and Gingerich and others (1990) take these vertebral proportions as evidence that *Basilosaurus* also had a tail fluke.

Further evidence that *Basilosaurus* spent most of its time in the water comes from another important change in the skull. This animal had a large single nostril that had migrated a short distance back to a point corresponding to the back third of the dental array. The movement from the forward extreme of the snout to a position nearer the top of the head is characteristic of only those mammals that live in marine or aquatic environments.

Dorudon

Dorudon was a contemporary of *Basilosaurus* in the late Eocene (about 40 million years ago) and probably represents the group most likely to be ancestral to modern whales (Gingerich 1994). *Dorudon* lacked the elongated vertebrae of *Basilosaurus* and was much smaller (about 4–5 meters in length). *Dorudon*'s dentition was similar to that of *Basilosaurus*; its cranium, compared to the skulls of *Basilosaurus* and the previous whales, was somewhat vaulted (Kellogg 1936). *Dorudon* also did not yet have the skull anatomy that indicates the presence of the apparatus necessary for echolocation (Barnes 1984).

Basilosaurus and *Dorudon* were fully aquatic whales (like *Basilosaurus*, *Dorudon* had very small

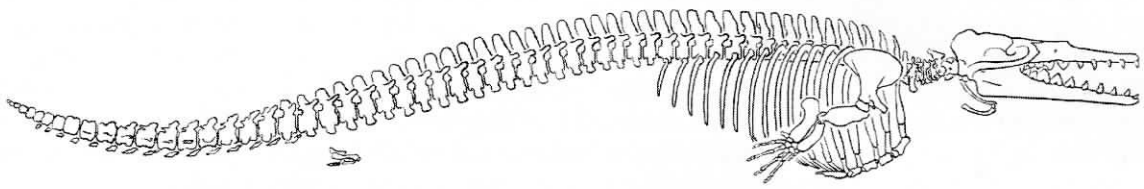


Gingerich and others (1994) published this recontruction of the skeleton of Rodhocetus kasrani *(redrawn for* RNCSE *by Janet Dreyer).*

hind limbs that may have projected slightly beyond the body wall). They were no longer tied to the land; in fact, they would not have been able to move around on land at all. Their size and their lack of limbs that could support their weight made them obligate aquatic mammals, a trend that is elaborated and reinforced by subsequent whale taxa.

Clearly, even if we look only at the paleontological evidence, the creationist claim of "No fossil intermediates!" is wrong. In fact, in the case of whales, we have several, beautifully arranged and in morphological and chronological order.

In summarizing the paleontological evidence, we have noted the consistent changes that indicate a series of adaptations from more terrestrial to more aquatic environments as we move from the most ancestral to the most recent species. These changes affect the shape of the skull, the shape of the teeth, the position of the nostrils, the size and structure of both the forelimbs and the hindlimbs, the size and shape of the tail, and the structure of the middle ear as it relates to directional hearing underwater and diving. The paleontological evidence records a history of increasing adaptation to life in the water — not just to any way of life in the water, but to life as lived by contemporary whales.



Gingerich and Uhen (1996) published this recontruction of the skeleton of Dorudon atrox *(redrawn for* RNCSE *by Janet Dreyer).*

2. Morphological evidence

The examination of the morphological characteristics shared by the fossil whales and living ungulates makes their common ancestry even clearer. For example, the anatomy of the foot of *Basilosaurus* allies whales with artiodactyls (Gingerich and others 1990). The axis of foot symmetry in these fossil whales falls between the 3rd and 4th digits. This arrangement is called paraxonic and is characteristic of the artiodactyls, whales, and condylarths, and is rarely found in other groups (Wyss 1990).

Another example involves the incus (the "anvil" of the middle ear). The incus of *Pakicetus*, preserved in at least one specimen, is morphologically intermediate in all characters between the incus of modern whales and that of modern artiodactyls (Thewissen and Hussain 1993). Moreover, the joint between the malleus (hammer) and incus of most mammals is oriented at an angle between the middle and the front of the animal (rostromedially), while in modern whales and in ungulates, it is oriented at an angle between the side and the front (rostrolaterally). In *Pakicetus*, the first fossil cetacean, the joint is oriented rostrally (intermediate in position between the ancestral and derived conditions). Thus the joint has clearly rotated toward the middle from the ancestral condition in terrestrial mammals (Thewissen and Hussain 1993); *Pakicetus* provides us with a snapshot of the transition.

3. Molecular biological evidence

The hypothesis that whales are descended from terrestrial mammals predicts that living whales and closely related living terrestrial mammals should show similarities in their molecular biology roughly in proportion to the recency of their common ancestor. That is, whales should be more similar in their molecular biology to groups of animals with which they share a more recent common ancestor than to other animals that exhibit convergent similarities in morphology, ecology, or behavior. In contrast, creationism lacks any scientific basis for predicting what the patterns of similarity should be, for there is no scientific way to predict how the creator decided to distribute molecular similarities among species.

Molecular studies by Goodman and others (1985) show that whales are more closely related to the ungulates than they are to all other mammals — a result consistent with evolutionary expectations. These studies examined myoglobin, lens *alpha*-crystallin A, and cytochrome *c* in a study of 46 different species of mammals. Miyamoto and Goodman (1986) later expanded the number of protein sequences by including *alpha-* and *beta-* hemoglobins and ribonuclease; they also increased the number of mammals included in the study to 72. The results were the same: the whales clearly are included among the ungulates. Other molecular studies on a variety of genes, proteins, and enzymes by Irwin and others (1991), Irwin and Arnason (1994), Milinkovitch (1992), Graur and Higgins (1994), Gatesy and others (1996), and Shimamura and others (1997) also identified the whales as closely related to the artiodactyls, although there are differences in the details among the studies.

By placing whales close to, and even firmly within, the artiodactyls, these molecular studies confirm

the predictions made by evolutionary theory. This pattern of biochemical similarities *must* be present if the whales and the ungulates, especially the artiodactyls, share a close common ancestor. The fact that these similarities *are* present is therefore strong evidence for the common ancestry of whales and ungulates.

4. Vestigial evidence

The vestigial features of whales tell us two things. They tell us that whales, like so many other organisms, have features that make no sense from a design perspective — they have no current function, they require energy to produce and maintain, and they may be deleterious to the organism. They also tell us that whales carry a piece of their evolutionary past with them, highlighting a history of a terrestrial ancestry.

Modern whales often retain rod-like vestiges of pelvic bones, femora, and tibiae, all embedded within the musculature of their body walls. These bones are more pronounced in earlier species and less pronounced in more recent species. As the example of *Basilosaurus* shows, whales of intermediate age have intermediate-sized vestigial pelves and rear limb bones.

Whales also retain a number of vestigial structures in their organs of sensation. Modern whales have only vestigial olfactory nerves. Furthermore, in modern whales the auditory meatus (the exterior opening of the ear canal) is closed. In many, it is merely the size of a thin piece of string, about 1 mm in diameter, and often pinched off about midway. All whales have a number of small muscles devoted to nonexistent external ears, which are apparently a vestige of a time when they were able to move their ears — a behavior typically used by land animals for directional hearing.

The diaphragm in whales is vestigial and has very little muscle. Whales use the outward movement of the ribs to fill their lungs with air. Finally, Gould (1983) reported several occurrences of captured sperm whales with visible, protruding hind limbs. Similarly, dolphins have been spotted with tiny pelvic fins, although they probably were not supported by limb bones as in those rare sperm whales. And some whales, such as belugas, possess rudimentary ear pinnae — a feature that can serve no purpose in an animal with no external ear and that can reduce the animal's swimming efficiency by increasing hydrodynamic drag while swimming.

Although this list is by no means exhaustive, it is nonetheless clear that the whales have a wealth of vestigial features left over from their terrestrial ancestors.

5. Embryological evidence

Like the vestigial features, the embryological features also tell us two things. First, the whale embryo develops a number of features that it later abandons before it attains its final form. How can creationism explain such seemingly nonsensical process, building structures only to abandon them or to destroy them later? Darwin (1859) asked the same question. Would it not make more sense to have embryos attain their adult forms quickly and directly? It seems unreasonable for a perfect designer or creator to send the embryo along such a tortuous pathway, but evolution requires new features to be built on the foundation of previous features that are modified or discarded later.

Second, the embryology of the whale, examined in detail, also provides evidence for its terrestrial ancestry. As embryos no less than as adult animals, whales are junkyards, as it were, of old, discarded features that are of no further use to them. Many whales, while still in the womb, begin to develop body hair. Yet no modern whales retain any body hair after birth, except for some snout hairs and hairs around their blowholes used as sensory bristles in a few species. The fact that whales possess the genes for producing body hair shows that their ancestors had body hair. In other words, their ancestors were ordinary mammals.

In many embryonic whales, external hind limb buds are visible for a time but then disappear as the whale grows larger. Also visible in the embryo are rudimentary ear pinnae, which disappear before birth (except in those that carry them as rare atavisms). And, in some whales, the olfactory lobes of the brain exist only in the fetus. The whale embryo starts off with its nostrils in the usual place for mammals, at the tip of the snout. But during development, the nostrils migrate to their final place at the top of the head to form the blowhole (or blowholes).

We can also understand evolution *within* the whales via their embryology. We know that the baleen whales evolved from the toothed whales: some embryos of the baleen whales begin to develop teeth. As with body hair, the teeth disappear before birth. Since there is no use for teeth in the womb, only inheritance from a common ancestor makes any sense; there is no reason for the intelligent designer or special creator to provide embryonic whales with teeth. So we have yet another independent field in complete accord with the overall thesis — that whales possess features that connect them with terrestrial mammalian ancestors, in particular the hoofed mammals.

6. Geochemical evidence

The earliest whales lived in freshwater habitats, but the ancestors of modern whales moved into saltwater habitats and thus had to adapt to drinking salt water. Since fresh water and salt water have somewhat different isotopic ratios of oxygen, we can predict that the transition will be recorded in the whales' skeletal remains — the most enduring of which are the teeth. Sure enough, fossil teeth from

the earliest whales have lower ratios of heavy oxygen to light oxygen, indicating that the animals drank fresh water (Thewissen and others 1996). Later fossil whale teeth have *higher* ratios of heavy oxygen to light oxygen, indicating that they drank salt water. This absolutely reinforces the inference drawn from all the other evidence discussed here: the ancestors of modern whales adapted from terrestrial habitats to saltwater habitats by way of freshwater habitats.

7. Paleoenvironmental evidence

Evolution makes other predictions about the history of taxa based on the "big-picture" view of the fossils in a larger, environmental, context. The sequence of whale fossils and their changes should also relate to changes observed in the fossil records of other organisms at the same time and in similar environments. The fossils of other organisms associated with the whale fossils indicate the environment that the whales lived in. Furthermore, this evidence should be consistent with the evidence from the other areas of study. We should expect to find evidence for a series of transitional environments, from fully terrestrial to fully marine, occupied by the series of whale species in the fossil record.

The morphology of *Sinonyx* indicates that it was fully terrestrial. It should be no surprise, therefore, that its fossils are found associated with the fossils of other terrestrial animals. *Pakicetus* probably spent a lot of time in the water in search of food. Although the mammalian fauna found with *Pakicetus* consists of rodents, bats, various artiodactyls, perissodactyls and probiscideans, and even a primate (Gingerich and others 1983), there are also aquatic animals such as snails, fish, turtles and crocodilians. Moreover, the sediment associated with *Pakicetus* shows evidence of streaming or flowing, usually associated with soils that are carried by water. The paleoenvironmental evidence thus clearly shows that *Pakicetus* lived in the low-lying wet terrestrial environment, making occasional excursions into fresh water. Interestingly, both deciduous and permanent teeth of the animal are found in these sediments with about the same frequency, supporting the idea that *Pakicetus* gave birth on the land.

The sediments in which *Ambulocetus* was found contain leaf impressions as well as fossils of the turret-snail *Turritella* and other marine mollusks. Clearly, the presence of such fossils must mean that the *Ambulocetus* fossil was found in what was once a shallow sea — although leaves can be washed into the sea and fossilize there, marine mollusks would not be found on the land.

Rodhocetus is found in green shales deposited in the deep-neritic zone (equivalent to the outer part of the continental shelf). Because green shales are associated with fairly low-oxygen bottom waters, *Rodhocetus* must have lived at a greater water depth than any previous cetacean. The fact that it is found in association with planktonic foraminiferans and other microfossils agrees with this determination of water depth. *Basilosaurus* and *Dorudon* have been found in a variety of sediment types (Kellogg 1936), indicating that they were wide-ranging and capable of living in deep as well as shallow water.

From the paleoenvironmental evidence, we can clearly see that, as whales evolved, they made their way into deeper water and became progressively liberated from the terrestrial and near-shore environments.

8. Paleobiogeographic evidence

The geographic evidence is also consistent with the expected distributional patterns for the whale's first appearance and later geographic expansion. We would expect terrestrial species to have a more restricted geographic distribution than marine species, which have essentially the whole ocean as their geographic range. The range of *Sinonyx* is restricted to central Asia. Specimens of *Pakicetus* have only been found in Pakistan; *Ambulocetus* and *Rodhocetus* seem to be similarly restricted. In contrast, *Basilosaurus* and *Dorudon*, representing the whales more adapted to living in the open sea, are found in a much wider area. Their fossils have been found as far away from southern Asia as Georgia, Louisiana, and British Columbia.

During the Eocene, most of the areas in which fossils of the later whales have been found were fairly close to one another. In fact, most of them are along the outer margin of an ancient sea called the Tethys, the remnants of which today are the Mediterranean, the Caspian, the Black, and the Aral Seas. The biogeographic distribution of fossil whales matches the pattern predicted by evolution: whales are initially found in a rather small geographic area and did not become distributed throughout the world until after they evolved into fully aquatic animals that were no longer tied to the land.

9. Chronological evidence

The final strand of evidence in our mutually consistent picture of whale origins comes from a consideration of why the whales originated *when* they did. Evolution is a response to environmental challenges and opportunities. During the early Cenozoic, mammals were presented with a new set of opportunities for radiation and diversification due, in part, to the vacuum left by mass extinctions at the close of the Cretaceous Period. Because the reptiles no longer predominated, there were new ways in which mammals could make a living.

In the specific case of whales, the swimming reptiles of the world's oceans could no longer keep the mammals at bay. Before the late-Cretaceous extinctions, the Mesozoic marine reptiles such as the plesiosaurs, ichthyosaurs, mosasaurs, and marine crocodiles might well have feasted upon any mammal that strayed off shore in search of food. Once those

predators were gone, evolution quickly produced mammals, including whales, that were as at home in the seas as they once were on land. The transition took some 10–15 million years to produce fully aquatic, deep-diving whales with directional underwater hearing. Evolution predicts that whales could not have successfully appeared and radiated before the Eocene, and that mammals should have radiated into marine environments as they did into a wide variety of other environments vacated by the reptiles at the end of the Cretaceous.

Conclusion

Taken together, all of this evidence points to only one conclusion — that whales evolved from terrestrial mammals. We have explored 9 independent areas of study that provide evidence that whales share a common ancestor with hoofed mammals. The power of evidence from independent areas of study that support the same conclusion makes refutation by special creation scenarios, personal incredulity, the argument from ignorance, or "intelligent design" scenarios entirely unreasonable. The only plausible scientific conclusion is that whales did evolve from terrestrial mammals. So no matter how much anti-evolutionists rant about how impossible it is for land-dwelling, furry mammals to evolve into fully aquatic whales, the evidence itself shouts them down. This is the power of using mutually reinforcing, independent lines of evidence. I hope that it will become a major weapon to strike down groundless anti-evolutionist objections and to support evolutionary thinking in the general public. This is how real science works, and we must emphasize the process of scientific inference as we point out the conclusions that scientists draw from the evidence — that the concordant predictions from independent fields of scientific study confirm the same pattern of whale ancestry.

Acknowledgements

I would like to thank Dr Philip Gingerich for his assistance with and review of this article.

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Before It's Too Late

Bearing the admonitory title *Before It's Too Late*, the report of the National Commission on Mathematics and Science Teaching for the 21st Century — informally, the Glenn commission, after its chair, John Glenn — was released on September 27, 2000. The report is the product of a year-long series of meetings conducted by the 25-member panel of educators, politicians, businesspeople, and researchers, including NCSE Supporter Bruce Alberts, President of the National Academy of Sciences.

The major points of the report, as summarized by Glenn in the foreword (pages 4-6), are:

First ... the future well-being of our nation and people depends not just on how well we educate our children generally, but on how well we educate them in mathematics and science specifically.

Second ... we are not doing the job that we should do — or can do — in teaching our children to understand and use ideas from these fields.

Third ... the most powerful instrument for change, and therefore the place to begin, lies at the very core of education — *with teaching itself.*

Fourth ... committing ourselves to reach three specific goals can go far in bringing about the basic changes we need. ...

> Establish an ongoing system to improve the quality of mathematics and science teaching in grades K-12;
>
> Increase significantly the number of mathematics and science teachers and improve the quality of their preparation; and
>
> Improve the working environment and make the teaching profession more attractive for K-12 mathematics and science teachers.

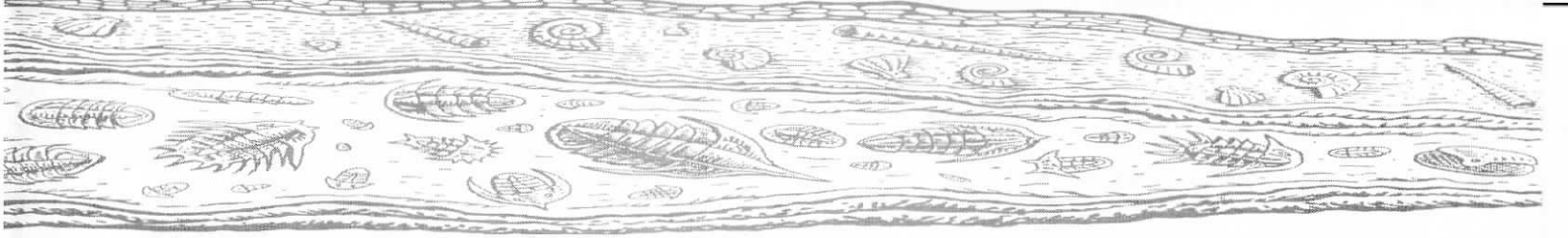
The commission was silent about the content of the mathematics and science curricula; according to the Washington *Post*, "Glenn said the panel avoided the content to be taught because the standards-setting done by professional groups representing science and math scholars and teachers has set the nation on the right path."

Before It's Too Late is available on the World Wide Web at <http://www.ed.gov/americacounts/glenn>; copies are also available by calling 1-877-433-7827 or 1-800-872-5327, e-mailing edpubs@inet.ed.gov, or writing to ED Pubs, Education Publications Center, US Department of Education, PO Box 1398, Jessup MD 20794-1398.

Looking for Life in All Sorts of Places

Mark Joiner

Recently, during my weekly journey upstairs to the lab library to peruse the contents of the lates the cover of *The Biological Bulletin* (1999; 196 [3]) published by the Marine Biological Laboratory (MBL) at Woods Hole, Massachusetts. Not only was the cover unusual, but the title, "Evolution: The Molecular Point of View", struck me as quite odd. As I flipped to the contents page, I saw listed there nearly 30 papers from a workshop of the same name, held at the MBL in October 1997. The papers presented dealt with the problems and progress of abiogenesis, bridging the prebiotic and RNA worlds, the prokaryotic-eukaryotic split, phylogenies of bacteria, Archaea and assorted really little guys, gene transfer, constraints on molecular



evolution, and other topics, including the origins and evolution of the AIDS viruses.

What also struck me as odd was that the workshop was sponsored by the NASA-sponsored Center for Advanced Studies in the Space Life Sciences (CASSLS) *at the MBL*! Space Life Sciences at the Marine Biological Laboratory? This was something I had to find out more about. A quick surf over to the MBL web site located the CASSLS homepage, and there I learned that there had been several of these workshops presented over the past few years (with the next one scheduled for September). Better yet, the abstracts were available on-line!

Now, what interest, you may ask as I did, would NASA (CASSLS) have with the biological sciences other than the obvious effects on organisms during space travel and in zero gravity (which is the topic of an upcoming workshop)? I feel that the article by Margulis and others summed it up best:

> Many of the stated goals of the 1958 Space Act were meant to generate new knowledge about the universe at large, but the statement that has most directly concerned molecular evolution is the following: A major goal of the National Aeronautics and Space Administration is to understand the origin and evolution of life as a phenomenon in the solar system [or wherever in the universe it may reside]. Three objectives are seen as fundamental to planetary biology and chemical evolution: (1) understanding the origin and evolution of life; (2) understanding the cycles that sustain life — the interactions between the physical, chemical and biological phenomena on the surface of the planet Earth; and (3) understanding the effects of life, both past and present, on the planet. Clearly the stated goals of planetary biology and chemical evolution of the National Academy's Space Science Board are congruent with the evolutionary ones of the NASA-sponsored [CASSLS] at the [MBL] (Margulis and others 1999: 413).

Although there have been both progress and problems in this area of research, the "problems" seem to draw the attention of anti-evolutionists — especially when they are arguing against evolution to the general public or to their committed supporters. However, even with its "problems", this research avoids the pitfalls obvious in the "research" of creation scientists — the futility and counterproductivity of creation science in general.

Discussing the controversies and disagreements among scientists in this emerging field, W Ford Doolittle gave his take on the nature of the barriers science must inevitably face:

> Science is supposed to work through cycles of hypothesis formulation, casting and then testing predictions, and finally hypothesis confirmation, rejection, or reformulation. Sometimes we, and even more often our public, forget this. We and they sometimes see times of turmoil (such as that in which early cell evolution now seems to be) as evidence of the failure of the scientific enterprise — that the experts were wrong once again. In fact, turmoil and confusion show us that science is working as it should. Some of our hypotheses should fail or need drastic reformulation, and we should rejoice in the opportunity to invent new ways of thinking about patterns in the data (Doolittle 1999: 378).

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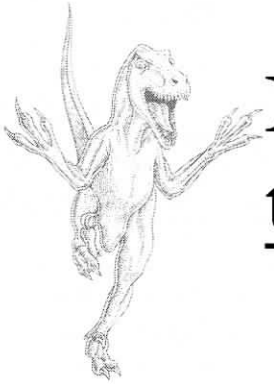

Letters to the Editor

I thoroughly enjoyed Kenneth R Miller's clear and thorough dissection of the proposed Oklahoma disclaimer (*see* RNCSE *2000; 20 [3]: 30-3*), which is so similar to Alabama's shameful disclaimer. Dr Miller completely demolished the disclaimer, leaving it a smoking ruin. My only complaint is that he refrained from dancing on the rubble. I note two serious errors in the disclaimer that Miller did not mention.

The first of these is in the first sentence: "This textbook discusses evolution ... [a] scientific explanation for the origin of living things..." Actually, biological evolution, the subject of the disclaimer, is not concerned with the origin of living things at all — biological evolution is concerned with how living things change in response to mutation, sexual reproduction, and natural selection. The origin of life from non-living materials is a worthy subject of study, and we know something about it thanks to many researchers working over the past 40 years or so, but I think it is misleading at best to focus on this as the main subject matter of biological evolution. One danger of allowing this error to stand unchallenged is the fact that we know so much more about the evolution of life than we do about the origins of life. There are legitimate disagreements about how life evolved from non-living matter, and ideas about how this happened are hypotheses, not theories. By contrast, you could fill an entire library with evidence documenting and explaining how evolution works and how the evolutionary process has played out on earth over the past 3.5 gigayears or so.

The second error concerns the disclaimer's statement that "macroevolution ... has never been observed." Miller correctly pointed out that evolution above the species level has in fact been observed, but he could have made a stronger case. Much of plant evolution happens very quickly, and new plant species have arisen by chromosome doubling in historical times — not once, but frequently. This kind of evolution has been documented at great length in the botanical literature. Specialists have also documented many cases of the appearance of new disease-causing microorganisms in historical times. I should add that the rapid evolution of pathogens is a powerful reason for studying evolution!

Once again, thank you for publishing such a wonderful article.

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Reading paleontologist Kevin Padian's hagiographic obituary of Thomas Jukes, Professor of Medical Physics at the University of California at Berkeley, one is impressed by this ambitious man's scientific versatility and accomplishments and by his effective defense of the teaching of evolution in our schools (*see* RNCSE *1999; 19 [6]: 10-1*). Nevertheless, his sporadic opposition to the environmentalism of the 1960s and 1970s, and especially his unfortunate opposition to the banning of DDT, deserves condemnation.

Admittedly, Jukes's views were motivated by humanitarian concerns for the victims of malaria, which DDT at that time was still able to control (ironically, however, Darwinian evolution by natural selection has since allowed DDT-resistant mosquitoes to evolve, and malaria is now returning with a vengeance). But Jukes ignored or downplayed the ecological and physiological effects of DDT, and his writings were prominently quoted by the chemical industry and its propaganda machine (*see Rita Gray Beatty,* The DDT Myth: Triumph of the Amateurs, *New York: John Day, 1973*) at various times in the years-long, ultimately successful battle to ban DDT in Wisconsin (1970) and the nation (1973), in which I took an active part.

By the 1970s, DDT and its long-lived breakdown products, such as DDE, were shown to be endocrine disruptors in vertebrates, especially birds. This has now led to the hypothesis that contamination of wildlife populations with such compounds can significantly alter embryonic sexual development. Furthermore, researchers are concerned that such adverse effects on male sexual differentiation could occur in humans as well.

The massive scientific research on DDT over the past 50 years has been summarized in *Our Stolen Future* (Theo Colborn, Dianne Dumanoski, and John P Myers, New York: Dutton, 1996), a book that deserves an honored place next to Rachel Carson's *Silent Spring* of 1962 and should be on every biology teacher's and school library's shelf. All evidence now points to the enormous harm that can come from these now practically ubiquitous compounds. Yet information on DDT is still being distorted by powerful chemical and agricultural interests (*see Sheldon Krimsky*, Hormonal Chaos: The Scientific and Social Origins of the Environmental Endocrine Hypothesis *[Baltimore: Johns Hopkins University Press, 2000], a book that will be of par-*

ticular value to RNCSE *readers interested in the history of science*).

The discovery of endocrine disruptors makes the subject of DDT one with the most serious implications and challenges Jukes's view (as reported by Padian) that "... although the public may still largely accept the view that DDT is dangerous, the scientific support for this view has largely evaporated." As I have shown, this is simply not true. Like the fight to legitimize Darwinian evolution, the fight for preserving the results of such evolution — the diversity of life on earth — must not be undermined by such misleading comments, certainly not in *RNCSE*.

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Here in Tennessee, we have our fair share of problems, but we are not nearly as bad off as the Fordham Foundation's report would lead you to believe (*RNCSE* 2000; 20 [4]: 44-6).

The Fordham Foundation reviewed our K-12 Science Framework as though it were a curriculum guide, which it is not! We are now in the process of preparing curriculum guides for K-8 science and for each high school science course, but of course these were not available to the Fordham Foundation team when it conducted its review.

One curriculum guide that is already approved by the state school board is that for Biology I. Beginning next year, every student in a public high school in Tennessee will have to pass Biology I as well as a state-contracted written test on Biology I content in order to graduate with a regular diploma. There are six content standards in Biology I, one of which is Biological Evolution! The Biology I Standards can be accessed on-line at <http://170.142.130.39/gate/> by clicking on Search Database, selecting Biology, and clicking on Start Search. The draft of the K-8 Science Standards does not explicitly use the "E-word", but the foundation is certainly being laid in K-8 for the Biology I course. For example, interpretation of fossil evidence is a strong recurring theme.

Applying the grading approach often used in elementary schools, I would give Tennessee a grade of "Making Progress" — a hopeful sign.

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WEB LOCATIONS VISITED IN THIS ISSUE

NEWS

TOPIC Anti-evolution Bill Down and Out in Arkansas — For Now
OWNER Arkansas State Legislature
LOCATION <http://www.arkleg.state.ar.us/ftproot/bills/2001/htm/HB2548.pdf>
LAST VISIT June 15, 2001

TOPIC Anti-evolution Bill Down and Out in Arkansas — For Now
OWNER Wesley Elsberry
LOCATION <http://inia.cls.org/~ae/ar_hb2548.htm>
LAST VISIT June 15, 2001

TOPIC Anti-evolution Bill Down and Out in Arkansas — For Now
OWNER Kent Hovind
LOCATION <http://www.drdino.com/Articles/Arkansas.jsp>
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TOPIC Rodney LeVake Loses Appeal
OWNER Minnesota State Court System
LOCATION <http://www.lawlibrary.state.mn.us/archive/ctappub/0105/c8001613.htm>
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RESOURCES

TOPIC Before It's Too Late
OWNER US Department of Education
LOCATION <http://www.ed.gov/americacounts/glenn>
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TOPIC Looking for Life in All Sorts of Places
OWNER Marine Biological Laboratory
LOCATION <http://hermes.mbl.edu/BiologicalBulletin/biol.bulletin.html>
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Reports of the National Center for Science Education (RNCSE) welcomes contributions from its readers and from anyone interested in issues related to evolution as the foundation for the biological sciences, to the place of evolution in the science curriculum, or to the public perception of scientific method and practice. These contributions may be submitted in one of two forms.

News, commentaries, and features describe events or experiences that we wish to relate to our readers and members. These may include reports of school-board elections or local organizing by parent and teacher groups, political or governmental decisions and policies, first-person accounts of experiences with anti-evolutionist speakers, curricula, or organizations, other reports of information related to our primary concerns of promoting good science in education and public life, and, of course, humor related to creation/evolution issues.

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   Kehoe AB. Modern anti-evolutionism: The scientific creationists. In: Godfrey LR, ed. *What Darwin Began*. Boston: Allyn and Bacon; 1985. p 165–85.

   Kuban GJ. Sea-monster or shark? An analysis of a supposed plesiosaur carcass netted in 1977. 1997; Available from <http://members.aol.com/paluxy2/plesios.htm>. Last accessed March 28, 1997.

   Smith FZ. Geocentrism re-examined. *Journal of Nice Things* 1985; 21-(3): 19–35.

   Waters IC, Rivers HI, and others. Swept away in a flood of enthusiasm [editorial]. *Reports of the National Center for Science Education* 2995 Jan–Feb; 1015 (1): 22–9.

   Zubrow E. *Archaeoastronomy*. Orlando (FL): Academic Press, 1985.

   Do not abbreviate names of publications. Include location of book publishers, and use the abbreviation "nd" for undated material. Multiple entries by the same author are listed in the bibliography in chronological order and those in same year are listed as: 1982a, 1982b, and so on.

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