

Evolving Into Science Advocates

"On October 26, 2007, Ms. Comer forwarded an e-mail from her TEA email account to a group of people that announced a presentation on creationism and intelligent design entitled 'Inside Creationism's Trojan Horse.' The e-mail states that the speaker is a board member of a science education organization that opposes teaching creationism in public education. Ms. Comer's e-mail suggests endorsement of the speaker and suggests that TEA endorses the speaker's position on a subject on which the agency must remain neutral."

-Excerpts from a memorandum concerning disciplinary action against Christine Castillo-Comer, the Director of Science for the Texas Education Agency (TEA), November 5, 2007.

"Florida Senator Ronda Storms, a Republican from Valrico, is taking on the theory of evolution. On Friday she introduced an Academic Freedom Act designed to tweak the state's recently adopted educational standard that calls for science teachers to teach evolution. Storms said the new bill merely says teachers should have the freedom to teach what they want, including theories that may contradict the prevalent theories of biological and chemical evolution. The bill does not mention creationism or intelligent design. The basis of her bill came from activists who failed in February to persuade the state Board of Education to allow the leeway. The board voted 4-3 two weeks ago to explicitly require the teaching of evolution."

-Reported by Keith Morelli in *The Tampa Tribune*, March 3, 2008.

With prominent American politicians dismissing evolution, the Texas educational authority claiming it must remain neutral regarding the teaching of evolution and not creationist viewpoints, and Florida in the midst of a heated debate on their new educational standards, puzzled scientists must once again scratch their heads in disbelief and ask what the heck is going on in this country? There is no doubt that evolution, while overwhelmingly accepted as fact in the scientific community, remains a contentious issue in the larger public domain and an especially troublesome one for some school boards. Among the favored tactics used to influence science curricula in public schools are the arguments that evolution is "just a theory not a fact," science teachers should be encouraged to "teach the controversy," and students should learn about so-called "alternatives to evolution," including intelligent design and other religious beliefs on the origin of life. So what exactly does the average American think about evolution and the importance of teaching about it in their children's science classes?

In an unusual show of solidarity, 17 scientific and educational societies-pooled their resources to support a na-

tional public opinion survey on how Americans feel about the teaching of evolution in public schools and on attitudes toward science and scientists. An additional goal was to explore ways of increasing their appreciation of the significance of evolution. This unique coalition of societies¹ represented science teachers, biologists, physicists, astronomers, chemists, and social scientists, and included such influential groups as the National Academy of Sciences (NAS) and the Federation of American Societies for Experimental Biology (FASEB).

The results, which were recently published in a coordinated manner in sev-

eral scientific journals,² newsletters,³ and on the Web (<http://opa.faseb.org/pages/PolicyIssues/sciencecoalition.htm>) were somewhat reassuring. The majority of respondents accepted that all life evolved (62%) and favored teaching evolution in sciences classes (53%). Similar to another recent study (Miller et al., 2006), the data showed a link between scientific knowledge and acceptance of evolution: Although only 23% of respondents were able to answer three basic science questions correctly, those who could were much more likely to favor the teaching of evolution in public schools than those who could not.

An important message of the survey was that the results unambiguously pointed to a role for scientists in sharing their knowledge with the public and in promoting quality science education. Respondents not only held the scientific community in high esteem (over 70% rated medical researchers favorably), but over 75% were interested in hearing

1. The Coalition of Scientific Societies includes the American Association of Physics Teachers, American Astronomical Society, American Chemical Society, American Institute of Biological Sciences, American Institute of Physics, American Physical Society, American Physiological Society, American Society for Investigative Pathology, American Society for Pharmacology and Experimental Therapeutics, American Society of Human Genetics, Biophysical Society, Consortium of Social Science Associations, Geological Society of America, Federation of American Societies for Experimental Biology, National Academy of Sciences, National Science Teachers Association, and the Society for Developmental Biology.

2. FASEB J [2008] 22:1–4 and Dev Biol [2008] 316:2–5.

3. ACA RefleXions, 2007. Number 4; The Pharmacologist, 2007. Volume 49(4); Physics and Society, 2008. Volume 37(1).

*Correspondence to: Marnie E. Halpern, Carnegie Institution for Science, Department of Embryology, 3520 San Martin Drive, Baltimore, MD 21208. E-mail: halpern@ciwemb.edu or Jennifer A. Hobin, Federation of American Societies for Experimental Biology, Office of Public Affairs, 9650 Rockville Pike, Bethesda, MD 20814–3998. E-mail: hobin@faseb.org

DOI 10.1002/dvdy.21548

Published online 11 April 2008 in Wiley InterScience (www.interscience.wiley.com).

from scientists, science teachers, and medical professionals on scientific topics, including evolution.

Americans' high opinion of scientists is an extension of the value they place on science itself. Recognizing the importance of science to improving public health, over 60% of respondents—regardless of whether they favored teaching evolution, creationism, or intelligent design—ranked developing drugs and curing disease as the most important contribution science makes to society. Moreover, 61% viewed the contribution of evolutionary biology to medical science as a convincing reason to teach the topic in science classrooms. These data underscore the importance of stressing the connection between evolution and scientific advancements to the public and the relevance of this knowledge to their health and well-being.

Nowhere is the topic of evolution more interconnected than with the study of developmental biology. Understanding the establishment of pattern and form in a developing embryo necessitates a greater appreciation of the genes that control these processes across species. It has become impossible to describe embryonic development without considering the conserved roles of transcription factors and members of signaling pathways, components of the so-called genetic toolkit, that are used reiteratively and in different contexts (refer to Carroll, 2005). The techniques of molecular biology provided us with an unprecedented ability to probe evolutionary relationships between organisms, developmental events, and anatomical structures, and led to the unified field of evolutionary developmental biology or “evo-devo” (for a nice historical review of the steps leading up to this synthesis see Gilbert, 2003). Nowadays, it is inconceivable to ask questions in developmental biology without considering their evolutionary framework (i.e., De Robertis, 2008). Furthermore, many of the conserved genes and regulatory pathways discovered by developmental biologists have been implicated in human diseases such as cancer.

However, outside of our own laboratories and lecture halls, is there an obvious way for developmental biologists to get the message out that an understanding and appreciation of evolutionary biology is critical to the advancement of scientific knowledge as well as to biomedical research?

Some of our colleagues have been deeply involved in this effort. A leader

of the evo-devo movement, Sean B. Carroll, has written two highly accessible and colorful books describing the many wondrous examples of biological diversity and their underlying molecular genetic logic (Carroll, 2005, 2006). Together with developmental biologist David Kingsley, he also designed a special lecture series on Charles Darwin and evolution for the Howard Hughes Medical Institute that was specifically geared for high school students and has served as a valuable teaching resource (<http://www.hhmi.org/biointeractive/evolution/index.html>).

Another developmental biologist concerned with students' ignorance of basic scientific facts took a different tack. Mike Klymkowsky, in addition to his “Leave No Child Behind: Teach Evolution” bumper sticker campaign, has spearheaded the Biological Concept Inventory Project (<http://bioliteracy.net/>) “to generate, test, and distribute tools needed to determine whether students are learning what teachers think they are teaching.” Ultimately, he and his colleagues expect these assessment tools will help undergraduates develop a deeper conceptual understanding of biological principles, including evolution (Klymkowsky and Garvin-Doxas, 2008).

Others have taken more radical approaches to educate the public about the difference between fundamental facts and fundamentalist viewpoints. Paul Z. Myers, a zebrafish developmental biologist, uses the power of the Internet. He developed his blog site *Pharyngula* (<http://scienceblogs.com/pharyngula>) as a discussion venue for, as he puts it, “evolution, development, and random biological ejaculations from a godless liberal.” On this highly popular, entertaining, and usually controversial site, Myers not only counters anti-evolution movements head-on, but he discusses biological topics as esoteric as the reproductive practices of cephalopods. *Pharyngula* was listed by *Nature* as the top-ranked science blog in 2005 and is still going strong.

The above are exemplary efforts that reflect extraordinary commitment to science education, but may be out of the realm of many tenure-seeking junior or overcommitted senior faculty. The question remains as to whether the rest of us can really make a difference in educating the public and ensuring that high quality science is a priority in American schools. In fact, there are a myriad of opportunities, running the gamut from quick and easy letter writing to participating in lo-

cal outreach activities or planning events at national meetings. In light of current initiatives and upcoming events, we provide a “top ten” list for ways that an individual scientist can participate in promoting science education and the teaching of evolution:

1. Learn about the issues. Recently, the National Academy of Sciences updated their instructive booklet *Science, Evolution, and Creationism*⁴ that provides a comprehensive review of the evidence for evolution and sets out the arguments in a clear and direct way (refer to Ayala, 2008). You can also peruse Judge John Jones's summary opinion on the *Kitzmiller v. Dover* case, in which he ruled that it is unconstitutional to teach intelligent design in public school science classrooms. The opinion is a masterful and scholarly document that not only summarizes the 2005 case but also outlines the tactics and logic flaws of current anti-evolution movements (http://www.pamd.uscourts.gov/kitzmiller/kitzmiller_342.pdf). Assaults on science education continue to appear at the local and state level with alarming regularity. Stay informed of these activities. The National Center for Science Education (NCSE), a nonprofit organization established to defend the teaching of evolution in public schools, maintains a useful listing of current events and a log of ongoing attempts to modify science curricula (<http://www.natcensci.org/>). You might be quite surprised to discover what anti-science initiatives are operating in your own state, county, or school district.
2. Weigh in on the debate. Write letters to your school board, public officials, and media outlets when anti-evolution initiatives emerge in your community. There are many useful resources to assist you in learning how to frame a letter or Op-Ed article so it will likely be published in your local newspaper (check out <http://opa.faseb.org/pages/PolicyIssues/evolutionresources.htm>).
3. Join and get involved in your state's *Citizens for Science*, “a network of grassroots organizations devoted to protecting and promoting science

4. National Academy of Sciences and Institute of Medicine (2008). *Science, Evolution, and Creationism*. Natl. Acad. Press: Washington, DC.

education"(http://citizensforscience.org/who_are_we). These groups foster communication and cooperative action on science education issues.

4. Celebrate the *Year of Science 2009* or organize a *Darwin Day 2009* event at your institution or in your community. The opportunities are limitless. Some already planned activities are public lectures on science, a scientific photography contest for students, and paleontology field trips (<http://www.copusproject.org/yearofscience2009> and <http://www.darwinday.org/englishL/home/2009.php>).
5. Start your own neighborhood *Science Café*. Cafes are popping up all over the country to provide an opportunity for people with no science background to engage in informal discussions of evolution and other scientific issues (<http://www.sciencecafes.org/what.html>).
6. Work with clergy members to organize a talk during Evolution Week-end 2009 or serve as a consultant to those who may have questions about the science associated with evolution (http://www.butler.edu/clergyproject/rel_evol_sun.htm). Dialogue between clergy and scientists is an effective way to communicate the importance of teaching evolution and that scientific and religious perspectives need not be incompatible. Indeed, when it came to the topic of evolution, respondents of the Coalition survey were eager to hear from clergy as well as from scientific professionals.
7. Put your scientific knowledge to use by offering to serve as a resource for science teachers or school boards who may need an expert lecturer on certain topics or help enriching curricular materials. A great example of science outreach is a project that brings a hands-on zebrafish developmental genetics unit to urban public schools (Schaefer and Farber, 2006). If you are more comfortable in your own environment, consider inviting high school students to visit your laboratory where they can see how science is conducted first-hand.
8. On the basis of your own research, write an article describing an interesting lesson plan or laboratory exercise that would be adaptable to the science classroom. A new journal *Evolution: Education and Outreach* recently made its debut with the goal of connecting science

teachers and scientists by publishing "cutting-edge, peer reviewed articles for classroom use on a variety of instructional levels" (<http://www.springer.com/life+sci/journal/12052>).

9. Become involved in your scientific society. Most, including the Society for Developmental Biology, and the American Association of Anatomists, which sponsors this journal, have active public affairs committees that address diverse policy issues and further these efforts through their membership with FASEB. You could also learn how to represent your society directly as a member of FASEB's Science Policy Committee.
10. Organize an evolution education workshop for teachers at your society's annual meeting. Such workshops provide the opportunity to share resources and promote interactions between scientists and science teachers. The University of California Museum of Paleontology partnered with NCSE to develop a blue print for organizing events of this kind (<http://www.ucmp.berkeley.edu/ncte/twb/>). Alternatively, work with your own academic institution to put together a summer program for teachers. It is not necessary to start from scratch as excellent models are already in place. For example, the SC Life program at Clemson University offers graduate courses and special summer workshops for middle and high school teachers, including one that is designed to help teachers better understand evolutionary theory, learn how scientists conduct research in evolutionary biology, and implement creative inquiry techniques to improve their students' comprehension of evolution. You can take advantage of SC Life course materials for your own nonprofit educational activities (<http://www.clemson.edu/SCLife/>). Teachers can have the greatest impact, but they need the engagement and support of scientists.

Although researchers may be reluctant or even apprehensive about showing a more public face and serving as science advocates, it is critical that we do so. The opponents of science literacy are not just sitting around. Their Web sites, articles, and books touting anti-evolution viewpoints are overwhelming, as has been the rising surge of initiatives to control school boards and mod-

ify science curricula. The strategies they employ might seem harmless enough (why not "teach the controversy"?) but their agenda clearly is not.

The survey by the Coalition of Scientific Societies demonstrates the essential part scientists can take in combating persistent efforts to diminish science education in the United States. Developmental biologists are clearly one group that has the expertise, the creativity, and the incentive to live up to this challenge.

ACKNOWLEDGMENTS

We thank the members of the FASEB Science Policy Subcommittee *Educating About Evolution* for their work on this issue and Carrie Wolinetz and Howard Garrison of FASEB for their helpful comments. M.E.H. also acknowledges the advice of Sally Kutzer and Lissa Rotundo, high school science teachers at the Baltimore Polytechnic Institute, and the Pew Science and Society Institute.

REFERENCES

- Ayala FJ. 2008. Science, evolution, and creationism. *Proc Natl Acad Sci U S A* 105:3-4.
- Carroll SB. 2005. Endless forms most beautiful: the new science of evo devo and the making of the animal kingdom. New York: WW Norton & Co.
- Carroll SB. 2006. The making of the fittest: DNA and the ultimate forensic record of evolution. New York: WW Norton & Co.
- Coalition of Scientific Societies. 2008. You say you want an evolution? A role for scientists in science education. *Dev Biol* 316:2-5.
- Coalition of Scientific Societies et al. 2008. Evolution and its discontents: a role for scientists in science education. *FASEB J* 22:1-4.
- De Robertis EM. 2008. Evo-devo: variations on ancestral themes. *Cell* 132:185-195.
- Gilbert SF. 2003. The morphogenesis of evolutionary developmental biology. *Int J Dev Biol* 47:467-477.
- Klymkowsky MW, Garvin-Doxas K. 2008. Recognizing student misconceptions through Ed's Tools and the Biology Concept Inventory. *PLoS Biol* 6:e3.
- Miller JD, Scott EC, Okamoto S. 2006. Public acceptance of evolution. *Science* 313:765-766.
- Schaefer J, Farber SA. 2004. Breaking down the stereotypes of science by recruiting young scientists. *PLoS Biol* 2:e279.

Marnie E. Halpern*

Carnegie Institution for Science
Department of Embryology
Baltimore, MD

Jennifer A. Hobin*

Federation of American Societies for
Experimental Biology
Office of Public Affairs
Bethesda, MD