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The best customer is an educated customer

Conscientious members of the retail industry have it right. The more information that is given to people, the better prepared they are to make wise purchases. A number of science educators in the United States could learn from this attitude. For the public to understand and support a national investment in scientific research, elementary and high school science education must provide thorough information on all scientifically well-established theories, including evolution — which is, arguably, the most important biological idea put forth in this millennium.

By now, most scientists will have heard that the Kansas State Board of Education has decided not to require (although they do not prevent) the teaching of the complete theory of evolution in Kansas schools, and most would probably agree that this represents a setback for science education in the United States. However, few scientists will have acted upon this opinion, taking comfort in the idea that this decision is an anomaly that will not affect the quality of scientific research in the US. That view is shortsighted — all scientists, structural biologists included, should be more concerned.

In the United States, science funding is dependent on public support. To support science, people must have a basic appreciation of its scope and value. It therefore follows that science education, at even the most basic level, is important and should be a primary focus of the scientific community. Children should learn to value the hallmarks of scientific thinking — assessment, skepticism, challenge, logical testing, and evaluation — which preclude a passive acceptance of all information as fact and encourage independent thinking. A better understanding of the scientific method would result in greater support for scientific research. Nevertheless, too few scientists become involved in education at the K–12 level, and few spend significant amounts of time trying to explain their research to the public.

Structural biology and evolution

Structural biologists benefit greatly from a public understanding of evolution. Many of the proteins amenable to structural research come from model organisms — *Escherichia coli*, *Saccharomyces cerevisiae*, *Drosophila melanogaster*, *Caenorhabditis elegans*, and so forth. Thus, it should be noted that work on model organisms is funded in large part because of the belief in evolutionary conservation — for example, a molecule that is important for a process such as DNA replication or repair in one organism is likely to be important for a similar process in humans. The structural genomics projects, which are natural extensions of the genome sequencing projects, also have a strong foundation in evolutionary theory.

Unfortunately, structural biology is often hard to explain to the public. Science writers and journalists tend to shy away from structural biology stories. Members of the public are generally interested in straightforward human health issues; so, the fact that reagents for structural biology are often obtained from model organisms, as noted above, rather than from humans, makes it more difficult to explain why the protein is interesting in a short news story. Moreover, despite the availability of interesting molecular 'pictures', structural research can seem esoteric, extremely complex, and too difficult to relate to everyday life. Thus, structural biologists should work harder to meet the challenge of reaching the public. This may require using the theory of evolutionary conservation to highlight the significance of certain types of research.

Improving science education

For a greater public appreciation of the importance of evolutionary theory, the principles of evolution must be taught in their entirety. Evolution should be presented as a logical physical explanation for a large amount of scientific data. The Kansas standards do, in fact, support the teaching of evolution — but only to a certain degree. They divide the theory of evolution into two topics: microevolution and macroevolution. Microevolution is defined as natural selection that leads to changes within species, whereas macroevolution covers the origins of the universe and of life on Earth, and the evolution of new species. The Kansas board encourages teaching of microevolution, including how mutations can result in selective advantages, but regards macroevolution as less substantiated and, therefore, not worth teaching. The Kansas guidelines are not mandatory, but if they are followed by teachers, they will effectively limit intellectual discussion of the theory of evolution, curtailing the development of scientific thinking. Students will not be encouraged to assess the evidence for the evolution of species and the origin of life and will thus be less exposed to a key aspect of scientific inquiry — debate.

Children are inquisitive by nature and respond well to learning by experimentation. If more science classrooms used the scientific method when approaching subjects such as evolution, more students would learn to value the process of questioning and experimenting. As a result, they would learn to think for themselves and would better understand the conclusions about evolution that have been drawn from the vast amount of scientific data that has been collected. Although the Kansas standards for science education do stress inquiry-based teaching overall, when it comes to evolution, their guidelines fall short of accomplishing this goal. Specifically, the Kansas guidelines do not include standards to address obvious questions that will arise from the study of both 'microevolution' and geology, such as: how old is the earth? How might life have begun? As a result, teachers may not be well equipped to handle such discussions scientifically.

In response to the Kansas decision, on September 23, 1999 three groups — the National Research Council, the American Association for the Advancement of Science, and the National Science Teachers Association — refused to grant permission to the Kansas State Board of Education to reprint portions of their educational materials, which had been modified to remove any mention of the origins of the universe and life on Earth (http://www.nationalacademies.org). This move is to be applauded. In response, the Kansas board has removed their guidelines from circulation and posted a statement on their web site which, as of this printing, reads: "The statewide science standards adopted by the Kansas Board of Education on Aug. 11, 1999, contained copyrighted material from several science organizations. Those organizations have since denied permission for that material to be used in the Kansas standards. Therefore, the state board is in the process of determining how to reword the Kansas science standards. Once that process is complete the standards will be posted on this web site" (http://www.ksbe.state.ks.us/outcomes/science_stds99.html). Thus, it appears that the last word on the science standards for the state of Kansas is yet to come.

Evolution in these pages

This issue of *Nature Structural Biology* highlights several topics that have evolutionary implications. On page 997, Philip Bevilacqua reviews the book *The RNA world*, which covers research that has obvious implications for the origin of life; on pages 1005, 1010, and 1016, the research groups of Chris Dobson, Luis Serrano, and David Baker investigate mechanisms of protein folding that appear to be conserved among proteins with similar topologies; and, on page 1062, Ron Breaker and colleagues use *in vitro* selection techniques to evolve a ribozyme to respond allosterically to cyclic nucleotides. Even from this random sampling of research in one journal, it is clear that an appreciation of modern scientific investigation depends on an understanding of evolution.

Plenty of scientists have found the origins of the universe and life on earth to be interesting and fruitful topics for research, and it would be a pity to limit the education of children in the United States to only certain aspects of evolutionary theory — a pity not only for them, but also for the future of scientific research in this country.