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Author: Haury, David L.
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"Nothing in Biology Makes Sense Except in the Light of Evolution." T. Dobzhansky.

What seemed like a provocative statement twenty years ago has become firmly

established as a unifying idea in biology education. Speaking at a convention of the National Association of Biology Teachers, Dobzhansky (1973) pointed out the remarkable diversity of life and the striking unity of life, both made more intelligible by the theory of evolution. He went on to say:

"Seen in the light of evolution, biology is, perhaps, intellectually the most satisfying and inspiring science. Without that light it becomes a pile of sundry facts-some of them interesting or curious but making no meaningful picture as a whole."

Evolution was also identified as the unifying theme of biology by the American Society of Zoologists (Moore, 1984); the Society's project to improve teaching at the college level first focused on evolutionary biology.

More recently, the National Research Council (NRC) (1996) identified evolution as a major unifying idea in science that transcends disciplinary boundaries; a powerful idea to be used across all grade levels to guide instruction and align the curriculum. Biological evolution was also listed as one of the six content areas in the life sciences that are important for all high school students to study. Following are the concepts and principles associated with this content standard (p. 185):

* Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring.

* The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms.

*Natural selection and its evolutionary consequence provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms.

* The millions of different species of plants, animals, and microorganisms that live on earth today are related by descent from common ancestors.

* Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities which reflect their evolutionary relationships. Species is the most fundamental unit of classification.

The American Association for the Advancement of Science (AAAS) (1993) also identified the evolution of life as one of six major areas of study in the life sciences. In addition to the guidelines provided by the NRC standards (1996), the AAAS emphasized genetics and molecular biology, and has suggested that students also know that:

* Molecular evidence substantiates the anatomical evidence for evolution.

* Heritable characteristics can be observed at molecular and whole-organism levels--in structure, chemistry, or behavior.

* New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells.

* Life on earth is thought to have begun as simple, one-celled organisms about 4 billion years ago. (p.125, abbreviated).

BARRIERS TO MEETING THE STANDARDS

A review of the literature on teaching and learning evolution (Demastes, Trowbridge, & Cummins, 1992) revealed several barriers, including certain intuitive ideas held by students, teleological and anthropomorphic thinking, and the influence of strongly held beliefs. These and other barriers have been discussed more fully at an evolution education research conference (Good and others, 1992), and in a special issue of the Journal of Research in Science Teaching (Volume 31, Issue 5, May 1994).
Whether one surveys school students, college students, teachers, or school administrators, findings reveal many misunderstandings regarding evolution, and substantial acceptance of pseudoscientific ideas (Brumby, 1984; Demastes, Settlage, & Good, 1995; Greene, 1990; Lord & Marino, 1993). In developing a teaching module on evolution, Bishop and Anderson (1986) identified several critical barriers that hinder student understanding, including:

1.Failure to make a distinction between the separate processes responsible for (a) the appearance of traits in a population and (b) the survival of such traits in the population over time.

2. Failure to recognize that natural selection is dependent on differences (in genetic traits and in breeding success) among individuals of a population.

3. Misinterpreting the nature of evolutionary change in populations, believing that all individuals change slowly over time. (pp. I-3)

INSTRUCTIONAL STRATEGIES

Scharmann (1993) has provided some general guidelines for designing lessons based on a conceptual change approach to instruction. It seems particularly crucial that teachers find ways to enrich the teaching of evolution given both the conceptual difficulty students have and the limited attention given to evolution in textbooks (Rosenthal, 1985; Glenn, 1990; Skoog, 1979).
Hilbish and Goodwin (1994) have pointed out that the standard approaches to teaching

natural selection through artificial examples and computer simulations show what could happen, not what is happening. They propose the use of real examples of natural selection in action, and they have described activities using the familiar dandelion. McComas (1991) also emphasized the importance of direct inquiry and has provided an annotated list of activities from non-textbook sources.

For teaching about human evolution, Offner (1994a, 1994b) has described activities using maps of human chromosomes to illustrate mechanisms of evolutionary change. Gipps (1991) described using casts of anthropoid skulls, and Riss (1993) suggested a related activity using photocopies of skulls.

THE "CREATIONIST" RESISTANCE

Perhaps most unsettling is the finding that a substantial proportion of high school biology teachers hold pseudoscientific beliefs, with nearly 40% thinking "there are sufficient problems with the theory of evolution to cast doubts on its validity" (Eve & Dunn, 1990). Those holding such views seem particularly vulnerable to the influence of various groups wishing to reduce attention to evolution in science classes. The teaching of evolution has been a source of controversy in American schools throughout the century (Larson, 1985; Nelkin, 1982), and advocates of evolution have continued to offer rebuttals to creationist claims (Berra, 1990; Ruse, 1982). In the early 1980s, the controversy led to a conference to clarify issues (Zetterberg, 1983). Though many scientific, religious, and educational organizations explicitly support the teaching of evolution (McCollister, 1989), many individuals also endorse the importance of upholding the integrity of science while also acknowledging the validity of deeply held religious beliefs (Hanson, 1986). Educators wanting more information supportive of evolution education from a Christian perspective may be interested in a resource packet, "Creationism, the church, and the public schools," available from the United Church of Christ Resources, Inc. (call 1-800-537-3394), or a booklet by the American Scientific Affiliation (ASA) entitled, "Teaching science in a climate of controversy." The ASA is an organization of Christians with academic degrees in science that takes no official position, but supports the teaching of evolution as science. Contact the ASA at P.O. Box 668, Ipswich, MA 01938-0668 (Call (508) 356-5656; E-mail: asa@newl.com)

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WHERE TO GO FOR HELP

INFORMATION CENTERS

Educational Resources Information Center (ERIC). The ERIC database includes

bibliographic information for approximately 800 items on the teaching and learning of evolution, from journal articles about classroom activities to research findings about student conceptions. Search the database using descriptors such as: evolution, biology, science education, science activities, science instruction, science curriculum, scientific concepts, genetics, misconceptions, creationism, and controversial issues course content For more information, contact ERIC/CSMEE, (800) 276-0462 or (614) 292-6717; Fax: (614) 292-0263; E-mail: ericse@osu.edu.

National Center for Science Education (NCSE). The NCSE sponsors several activities to support the teaching of evolution. The organization publishes a quarterly newsletter for members, and a semi-annual journal, Creation/Evolution. NCSE also distributes many books and sponsors many seminars and workshops. For more information, contact NCSE, P.O. Box 9477, Berkeley, CA 94709. Telephone: (800) 290-6006 or (510) 526-1674; Fax: (510) 526-1675; E-mail: ncse@crl.com.

INTERNET RESOURCES

Harvard's Evolution Virtual Library

http://golgi.harvard.edu/biopages/evolution.html

This World Wide Web server provides an extensive collection of Internet links to organizations, publications, academic programs, museums, collections, and exhibits. This is a good place to start a search for current information relating to evolution.

The Talk.Origins Archive

http://rumba.ics.uci.edu:8080/origins/faqs.html

This home page presents files from a UserNet group, talk.origins. Though strongly oriented toward issues relating to evolution and creation, this site presents some very readable essays on evolutionary theory, findings, and methods.

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