



Thinking Evolutionarily

Evolution Education
Across the Life Sciences

Steve Olson,
Jay B. Labov

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Across the Life Sciences

Summary of a Convocation

Steve Olson, *Rapporteur*
Jay B. Labov, *Editor*

Planning Committee on Thinking Evolutionarily:
Making Biology Education Make Sense

Board on Life Sciences, Division on Earth and Life Studies

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This convocation would not have been possible without the generous support of the Burroughs Wellcome Fund, the Christian A. Johnson Endeavor Foundation, the National Academy of Sciences, and the National Science Foundation through a Research Coordination Network/Undergraduate Biology Education grant to Oklahoma University (Gordon Uno, Principal Investigator). We thank all of them sincerely. We also thank Dr. Toby Horn, Carnegie Institution for Science, for her role in procuring the facilities of the Carnegie Institution for the convocation and in assisting with logistical planning for the event.

This summary has been reviewed in draft form by individuals cho-

sen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published summary as sound as possible and to ensure that the summary meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The reviewers' comments and draft manuscript remain confidential to protect the integrity of the process. We thank the following individuals for their review of this summary:

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Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the content of the report, nor did they see the final draft of the report before its release. The review of this report was overseen by Dr. Diane Ebert-May, Michigan State University. Appointed by the NRC, she was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the author and the institution.

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Introduction and Overview¹

Evolution is the central unifying theme of biology. Yet today, more than a century and a half after Charles Darwin proposed the idea of evolution through natural selection, the topic is often relegated to a handful of chapters in textbooks and a few class sessions in introductory biology courses. In many introductory biology courses (both undergraduate and high school), and even in some upper-level courses, evolution is not covered at all.

In recent years, a movement has been gaining momentum that is aimed at radically changing this situation. An increasing number of research scientists, educators, and education researchers are pointing to the many benefits of teaching evolution throughout the biology curriculum. Understanding evolutionary processes is essential to achieving a full understanding of the variety, relationships, and functioning of living things. An appreciation of evolutionary principles can enhance and enliven study of virtually all other areas of biology, such as embryological development, the spatial distribution of organisms, anatomy and physiology, behavior, interactions among organisms, processes of disease, the biological history of all species including humans, and a greater appreciation for biodiversity and the natural environment. Furthermore, teach-

¹ This report has been prepared by the workshop rapporteur as a factual summary of what occurred at the workshop. The planning committee's role was limited to planning and convening the workshop. The views contained in the report are those of individual workshop participants and do not necessarily represent the views of all workshop participants, the planning committee, or the National Research Council.

ing evolution across the curriculum can help counter the confusion and contention that still hinder the teaching of evolution in many classrooms, especially at the K-12 level, in the United States.

On October 25-26, 2011, the Board on Life Sciences of the National Research Council and the National Academy of Sciences held a national convocation in Washington, DC, to explore the many issues associated with teaching evolution across the curriculum. Titled "Thinking Evolutionarily: Evolution Education Across the Life Sciences," the convocation brought together people from many sectors, including K-12 education, higher education, museums, publishers, government, philanthropy, international educators, and non-profit organizations, who rarely communicate but need to work collaboratively if evolution is to assume a more prominent role in biology education. The goals of the convocation were to articulate issues, showcase resources that are currently available or under development, and begin to develop a strategic plan for engaging all of the sectors represented at the convocation in future work. It focused specifically on infusing evolutionary science into introductory college courses and into biology courses at the high school level, although participants also discussed learning in earlier grades and life-long learning. In addition, the convocation covered the broader issues associated with learning about the nature, processes, and limits of science, because understanding evolutionary science requires a more general appreciation of how science works.

This summary provides a narrative, rather than a chronological, overview of the presentations and rich discussions that occurred during the convocation. It is organized around the major themes that recurred throughout the event, including the structure and content of curricula, the processes of teaching and learning about evolution, the tensions that can arise in the classroom, and the target audiences for evolution education.

For a much more complete list of resources, see the annotated bibliography that is found in *Science, Evolution, and Creationism* (National Academy of Sciences and Institute of Medicine, 2008) and the resources found throughout the National Academy of Sciences' *Evolution Resources* webpage (<http://nationalacademies.org/evolution>). In addition, resources that were suggested prior to and following the convocation by planning committee members and participants can be found at <http://nas-sites.org/thinkingevolutionarily/additional-resources/>.

THE SETTING AND SPIRIT OF THE CONVOCATION

The convocation was held at the Carnegie Institution for Science in Washington, DC, which has supported major science initiatives throughout the 20th and 21st centuries. In her welcoming remarks at the convoca-

tion, Maxine Singer, a member of the National Academy of Sciences and Institute of Medicine, and President Emerita of the institution, recalled her service on the committee that wrote the first edition of the report *Science and Creationism* (National Academy of Sciences, 1984). The committee's meetings were enlivened by the exchanges of two accomplished physical scientists, she said. "One, an adamant, feisty, and cerebral non-believer, would have preferred us to offer bold language that set religion aside as a way to view the world. The other, a calm and at least as cerebral religious believer who was also firmly convinced by the evidence for biological evolution, urged us toward an understanding and tolerance of religion."

The committee listened carefully to this discussion, Singer said, and what it learned is captured in the eloquent conclusion to the 1984 report: "Scientists, like many others, are touched with awe at the order and complexity of nature. Religion provides one way for human beings to be comfortable with these marvels. However, the goal of science is to seek naturalistic explanations for phenomena within the framework of natural laws and principles and the operational rule of testability."

This is the spirit in which the convocation was held. "My hope," said Singer, "is that we all respect the religious beliefs of one another, of students and their families. I think you can find ways to teach evolution that are scientifically rigorous but avoid contentious challenges to individuals."

PERSPECTIVE OF A FUNDER

The convocation was funded by the National Academy of Sciences, the Burroughs Wellcome Fund, the Christian A. Johnson Endeavor Foundation, the Carnegie Institution for Science, and the National Science Foundation through a Research Coordination Network/Undergraduate Biology Education grant to the University of Oklahoma. A representative of one of the funders, Susan Kassouf, a program officer at the Johnson Endeavor Foundation, spoke in the opening session about some of the larger issues addressed during the convocation. She said that the mission of the Johnson Endeavor Foundation is to help people, especially young people, flourish. It has pursued this mission by helping to provide students with a liberal arts education that offers the best thinking of humanity. For this reason, among others, the foundation has become interested in understanding why so many Americans doubt evolutionary science when such doubt can have grave consequences not only for the individual but also for the larger society.

"Getting one's head, heart, and soul around the scientific theory of evolution and its implications is daunting," said Kassouf. "While our awe and wonder about the world may deepen in light of evolutionary

theory—indeed, evolution does seem miraculous—our minds may also boggle and buckle when coming to terms with a certain fundamental randomness and unpredictability, a lack of a grand design, a perception that the theory portends a loss of meaning and purpose in our lives. For all of these reasons and others, we applaud your efforts to make the scientific theory of evolution an integral part of young people’s introduction to biology and help them become comfortable with this fundamental, perhaps unsettling, idea.”

The theory of evolution can be seen to underlie our entire understanding of life, said Kassouf. Efforts such as the ones being discussed at the convocation are “a wise way to help us all begin to accept the soundness of evolutionary theory not just in our heads but in our hearts and minds.”

OVERVIEW OF THE CONVOCATION²

In his opening presentation, Gordon Uno, David Ross Boyd Professor at the University of Oklahoma, as well as a member of a group under the National Evolutionary Synthesis Center (NESCent) that first conceived of this convocation and a special consultant to the convocation’s organizing committee, laid out many of the central issues addressed at the event.

Teaching evolution across the curriculum makes sense both biologically and pedagogically, he said. (Chapter 2 describes some of the many curricular and instructional changes needed to teach evolution across the curriculum.) Many major science education reform movements have observed that students learn better when information is organized around major unifying concepts such as evolution (see Box 1-1). In biology, no concept is more unifying than evolution. The biologist Theodosius Dobzhansky wrote an article with the famous title, “Nothing in Biology Makes Sense Except in the Light of Evolution” (Dobzhansky, 1973). Uno offered a corollary: Everything in biology makes more sense in the light of evolution. “If we really want to help our students understand biology, shouldn’t we be teaching more evolution?”

Instructors and students should clearly understand the learning objectives for a course, Uno observed. Instructors then should ask what activities, lessons, and other experiences will help students reach those objectives. In this way, teachers have a constant reminder to be intentional in their instruction.

For the biology course he teaches, Uno’s reminder is: “Evolution—say it every day.” It is a challenge to incorporate something about evolution in every class taught in every course. But when Uno talks about cells, he

² Additional resources, including video archives and PowerPoint presentations of speakers and panelists, interviews with selected participants, and a list of useful references and websites are available at <http://nas-sites.org/thinkingevolutionarily/>.

BOX 1-1
Prominent Statements on Evolution Education

From the *National Science Education Standards* (National Research Council, 1996): As a result of activities in grades K–12, all students should develop understanding and abilities aligned with the following concepts and processes:

- Systems, order, and organization
- Evidence, models, and explanation
- Constancy, change, and measurement
- Evolution and equilibrium
- Form and function

From *Scientific Foundations for Future Physicians* (AAMC-HHMI, 2009), Competency E8: Demonstrate an understanding of how the organizing principle of evolution by natural selection explains the diversity of life on earth.

From *A Framework for K-12 Science Education* (National Research Council, 2011): Biological evolution explains both the unity and diversity of species and provides a unifying principle for the history and diversity of life on Earth.

From *Vision and Change in Undergraduate Biology Education: A Call To Action* (Brewer and Smith, 2011): The diversity of life evolved over time by processes of mutation, selection, and genetic change.

From *AP Biology Curriculum Framework: 2012-2013* (College Board, 2011): The process of evolution drives the diversity and unity of life.

From *Science, Evolution, and Creationism* (National Academy of Sciences and Institute of Medicine, 2008): Biological evolution is the central organizing principle of modern biology.

looks for opportunities to talk about endosymbiosis. When he teaches about photosynthesis, he provides evolutionary explanations for why plants do not absorb the green part of the visible spectrum and thus reflect green wavelengths of light. When he talks about cells, he also describes the same sorts of molecules in different organisms and the relevant evolutionary history. “Every single day I try to bring into the classroom something about evolution.”

As described in Chapter 3, education researchers still have much to learn about how students learn evolution and about the effects of an evolutionary understanding on other aspects of biology education. But Uno listed several questions that he asks students to gauge whether they are thinking evolutionarily: